Upset Recovery Training Program: Report on Training Effectiveness

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Loss-of-control in flight was the largest category of fatal commercial air carrier accidents between 1994 and 2003 (Boeing Commercial Airplanes Group, 2004). Thirty-two out of the 105 fatal accidents resulted in 2,670 deaths. Loss-of-control accidents were also the second leading cause of general aviation accidents in the United States and have been on the constant increase for all categories of flight for the past 25 years. The Flight Research Training Center, established in 2002, by the Alliance for Flight Safety Research in cooperation with the Federal Aviation Administration, provides specific training for pilots on dealing with upset events that can lead to loss-of-control. This document describes the methods for the collection of pilot performance data which was performed under the FAA funded Upset Recovery Training program for the period from August 8, 2002 through November 18, 2005. The report also details the results of the analysis of the collected data which was separately funded by NMDOT beginning in March 2005.
UPSET RECOVERY TRAINING PROGRAM:

Interim Report on Training Effectiveness

by

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PREFACE

The fundamental goals of the Upset Recovery Training and research program are (a) to conduct research to optimize in-flight simulation-based Upset Recovery Training, (b) meet the pilot training needs of commercial air carriers, (c) to design and develop In-Flight Safety technology and systems specifically for the upset recovery training role, and (d) to have a beneficial impact on the loss-of-control accident, incident, and event rate. This document describes the methods for the collection of pilot performance data which was performed under the FAA funded Upset Recovery Training program for the period from August 8, 2002 through November 18, 2005. The report also details the results of the analysis of the collected data which was separately funded by NMDOT beginning in March 2005.

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DISCLAIMER

This report presents the results of research conducted by the author(s) and does not necessarily reflect the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.
ABSTRACT

Loss-of-control in flight was the largest category of fatal commercial air carrier accidents between 1994 and 2003 (1). Thirty-two out of the 105 fatal accidents resulted in 2,670 deaths. Loss-of-control accidents were also the second leading cause of general aviation accidents in the United States and have been on the constant increase for all categories of flight for the past 25 years (2). The Flight Research Training Center, established in 2002, by the Alliance for Flight Safety Research in cooperation with the Federal Aviation Administration, provides specific training for pilots on dealing with upset events that can lead to loss-of-control. Alliance member organizations are the New Mexico Department of Transportation; Eastern New Mexico University at Roswell, The City of Roswell, New Mexico; CUBRC, Inc.; and the Calspan Corporation. This document describes the methods for the collection of pilot performance data which was performed under the FAA funded Upset Recovery Training program for the period from August 8, 2002 through November 18, 2005. The report also details the results of the analysis of the collected data which was separately funded by NMDOT beginning in March 2005.
ACKNOWLEDGMENTS

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INTRODUCTION

Loss-of-control in flight was the largest category of fatal commercial air carrier accidents between 1994 and 2003 (1). Loss-of-control accidents were also the leading cause of general aviation accidents in the U.S. in 2003 (2). These accidents have been on the constant increase for all categories of flight, for the past 25 years. In response to this issue, in 2002, the Flight Research Training Center was established in Roswell, New Mexico by the Alliance for Flight Safety Research, in cooperation with the Federal Aviation Administration (FAA), to provide specific training for pilots on dealing with upset events that can lead to loss-of-control.

Mandatory requirements for training pilots to respond to unexpected events, unusual attitudes, and/or upset situations which could lead to loss-of-control are inconsistent and in most cases vague. The only requirement for Federal Aviation Administration (FAA) pilot certification in the U.S. at the Private, Commercial, Air Transport Pilot, or Certified Flight Instructor level is for the applicant to “exhibit adequate knowledge of recovery from unusual attitudes” (3, and 4). Operations under U.S. Federal Aviation Regulations Part 91, Subpart K, Part 135, and Part 121 air carriers are not required to provide specific upset recovery training. However, there are a number of recommended practices and training programs addressing the loss-of-control issue.

As a result of the alarming number of loss-of-control accidents, the NTSB issued recommendation A-96-120 (5), requiring air carriers to provide training to flight crews in the recognition of and recovery from any unusual attitude, whether caused by flight control malfunctions or uncommanded control surface movement. Training should also
include upsets while the aircraft is being controlled by automatic flight control systems. In concert with this recommendation, the FAA issued a bulletin that strongly suggested air carriers include in their flight training programs rare, potentially life-threatening events that could lead to loss-of-control and an accident. This type of training was termed Selected Event Training (SET) (6). Its purpose was to broaden the standard training syllabus from common aircraft emergency and instrument operating procedures to those rare events such as recovery of the aircraft from extreme flight attitudes.

Although SET is not mandatory, most U.S. domestic air carriers have voluntarily incorporated at least some aspect of unusual attitude or upset training into their curricula. These programs attempt to prepare pilots to cope with aircraft upset events. They range from classroom instruction only to classroom instruction integrated with ground-based full-flight simulator sessions. In addition, the airline industry formed a team and developed an Airplane Upset Recovery Training Aid (7). The Training Aid includes a curriculum and training materials that the airlines can incorporate into their training programs. The program is structured to include classroom academics and ground-based simulators. It is unclear whether typical voluntary SET programs targeting unusual attitudes and upsets are successful in addressing the underlying causes and recovery techniques for loss-of-control. One limitation may be the exclusive use of ground-based simulators in the practice of recoveries.
UPSET RECOVERY TRAINING PROGRAM

Participant data from the Upset Recovery Training program offered at the Flight Research Training Center in Roswell, NM, was used in this study. This FAA sponsored training and research program consists of classroom instruction and flights in an aerobatic aircraft and an In-Flight Simulator (IFS) Learjet. This unique training protocol integrates human factors and training science into all aspects of the curriculum and includes in-flight training in an aerobatic Bonanza and an in-flight simulator Learjet. The Calspan developed Learjet IFS aircraft has a fly-by-wire flight control system that is programmed to represent the characteristics and feel of most corporate or transport category aircraft. The in-flight simulator replicates the characteristics of other aircraft by using sophisticated on-board computers. Similar to ground-based simulation, these computers are programmed with the aerodynamic and flight control data of the airplane to be simulated. The computer then controls the IFS aircraft so that it reproduces the handling characteristics of that aircraft. Furthermore, upset events are programmed into the system so the trainee can safely experience loss-of-control in the real world. This training targets the common thread found in nearly all upset-induced accidents; the crew was faced with an abnormal or unknown aircraft behavior.

The URT program has evolved over the past two years and the protocol has been updated to reflect participant and instructor evaluations of the protocol. For example, the
order of the training elements was rearranged and standardized to maximize the classroom and in-flight components of the training program. The revised protocol addressed previously voiced concerns regarding participant stress and fatigue, and airplane scheduling issues. Related projects have also been conducted with the study population data to investigate additional research questions ancillary to the training program and loss-of-control countermeasures (8, 9, 10, 11, 12, 13 and 14).
BACKGROUND

PROGRAM BACKGROUND

The fundamental goals of the FAA-URT project are (a) to conduct research to optimize In-Flight Simulation (IFS) based Upset Recovery Training (URT), (b) meet the pilot training needs of commercial air carriers, (c) to design and develop IFS technology and systems specifically for the URT role, and (d) to have a beneficial impact on the loss-of-control accident, incident, and event rate.

In addition, the intent of the program is to train 2,000 participants (primarily pilots from commercial airlines) over the course of the program which is expected to continue through 2007. This results in a program which is hybrid in nature creating two complementary, yet independent, activities: the research and the training. Quasi-experimental field studies inherently present a host of research obstacles which are amplified in this blended training and research arena. A balance must be reached between the need for efficient operations, in order to reach the necessary throughput, and the need to collect sufficient data to provide a basis for the optimization activity.

STRUCTURE OF THE PROGRAM

Since the inception of the program in 2002, the structure of the research and training protocol has been continually monitored and revised for the duration of the program.

Original Research Protocol

The structure of the research and training program for the first eighteen months of the study (August 8, 2002 through December 31, 2003) was composed of three modules and lasted two days. The first module was a classroom lecture where participants
received instruction in causes of upsets, aerodynamic fundamentals, and recovery techniques. The second module was usually a training flight in the Aerobatic Bonanza. The Bonanza flight exposed the pilot to general aircraft characteristics, G-force awareness, slow flight and stall awareness, limited aerobatics, and unusual attitude recoveries. The third module was the In-Flight Simulator (IFS) Learjet aircraft training where the participant experienced real-world upset events and practiced various recovery techniques. This module began with a flight rehearsal session using a ground-based (non-motion) simulator. Details on the program and training activities are available in the Upset Recovery Training Effectiveness Experiment Design Plan (16).

**Research Protocol Modifications**

Changes in the program protocol based on feedback from the first 201 participants of the program were made beginning in January, 2004. Evaluation forms from the participants and instructor comments regarding the structure of the program and the usefulness of each of the training elements were reviewed. Based on the high frequency of comments regarding the order of events in the training, the structure of the program was changed. This involved separating the classroom briefings into two sessions; one prior to the Bonanza flight and one prior to the ground simulator and Lear flight. Strict adherence to flying the Bonanza prior to the Lear was also implemented in response to comments from the participants. These modifications to the protocol changed the order of the presentation of elements; however the content of each module was not substantially altered. Although these changes appear to benefit the program, no significant differences in old protocol versus new protocol participant evaluation scores were found on any of the specific modules or for the course overall (17).
QUANTIFYING THE TRAINING EFFECTIVENESS

To optimize the in-flight simulation based upset recovery training, we needed to be able to measure how much the participant’s ability to recover, from a variety of upsets, improved during the training. We also needed to assess the value of the various events to the participant. Our initial research questions were (a) how much did the participant learn from the URT experience, and (b) what elements did the participant find most useful and why?

UPSET RECOVERY RATINGS

Measuring a pilot’s ability to recover is a difficult task. Unfortunately, the seemingly straightforward concept of measuring performance parameters such as reaction times, maximum bank or pitch angles, etc. may be inadequate in similar circumstances. The reasons for this are manifold and would require a separate document to discuss. Instead, this simple thought experiment from everyday experiences may best illustrate the difficulty of measuring how well a task is accomplished by measuring the performance.

Consider that a single driver has two cars; car “A” steers poorly, car “B” steers like a dream. If you follow each of these cars for 10 miles, with the same driver, you may not be able to tell which car drives the best. When car “A” is driven, the driver pays strict attention to the task and rarely strays from the center of the lane. When car “B” is driven, the driver’s attention may wander to other things resulting in straying further from the center of the lane than occurred with car “A”. To the outside observer, using quantitative measures, it might appear that car “A” handles better. However, the most expeditious (and perhaps accurate) way of finding out which car drove the best is to ask the driver who will be able to tell you unequivocally about the (a) mental and physical workload,
(b) level of apprehension and or stress, and (c) confidence experienced in performing the task. In this example, driver opinion would say car “B” performed better. Thus, in the long run, it may be much more cost effective and accurate to ask the driver to provide the performance evaluation.

Measuring the quality of a pilot’s recoveries to upset events presents a problem similar to the driving task. We must consider both the perceptual-motor performance, physical and mental workload, and the level of confidence one has in responding to an upset. Flight test organizations around the world have adopted the Cooper-Harper rating scale to facilitate quantifying aircraft handling qualities \( (18) \). The Cooper-Harper scale incorporates performance and workload measures to assist an evaluation pilot in determining a single rating of the handling qualities of a particular aircraft. The original Cooper-Harper Handling Quality Scale has been adapted to fit the needs of the URT program. The modified “Recovery Quality Rating Scale” is shown in Attachment. The scale is administered near the beginning of the flight to obtain a “beginning” rating and then again after practice near the end of the flight for an “ending” rating. These “beginning” and “ending” ratings did not intend to measure what had been learned from the entire course. Instead, the purpose of the scale is to help determine how much the participant learned specifically from the in-flight simulation upset recovery practice.

During this initial phase of the program, no effort was made to measure the amount learned in the entire course, or how much each element contributed to the overall program. However, participants did have an opportunity to comment on their perceptions of the elements and the benefit of the overall course as part of the post flight evaluation form.
PARTICIPANT’S EVALUATIONS OF THE PROGRAM

The second question of interest, how valuable was the course to the participant, was addressed by a post-flight evaluation form. This was filled out by the participant at the end of the entire course.

ADDITIONAL DATA COLLECTION

Background, training, and flight hours in various categories were provided by the participants. Time history data and display video data were also collected for future use. Data collected was separated into (a) information that could be associated with the participant’s name and (b) information identified only by randomly assigned participant identification numbers. The documents used to collect information which could be associated with the participant included:

- Contact form
- Consent form
- Certificate of Training (a Calspan Learjet requirement)
- Flight Release
- Flight Log
- Copy of Pilot License
- Copy of Pilot’s Medical Certificate

Documents and information associated with study data to be analyzed were only identified by the randomly assigned identification (ID) numbers for confidentiality. The study forms and materials indentified by ID number only were:

- Participant Training and Experience Background
- Participant Flight Time Background
• Recovery Quality Rating Scale
• Post Flight Evaluation of Upset Recovery Training
• DVD - Video of cockpit display
• CD ROM - Flight time-history data
• Beginning Recovery Rating
• Ending Recovery Rating
• Confidence in Rating

Table 1 and Table 2 provide a brief description, purpose, and use for each of the data items.
TABLE 1 Description and Purpose of Data Collection Forms.

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
<th>Purpose and Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant Training and Experience Background.</td>
<td>A document filled out by the participant that provides relevant demographic information.</td>
<td>This information is entered into a database so that correlations may be evaluated between these data and data collected in other items such as background and training experience versus participant competence in performing upset recoveries.</td>
</tr>
<tr>
<td>Participant Flight Time Background</td>
<td>A document filled out by the participant providing relevant flight times such as military, civilian, transport, or aerobatic.</td>
<td>This information is entered into a database so that correlations may be evaluated between these data and data collected during URT flights.</td>
</tr>
<tr>
<td>Recovery Quality Rating Scale</td>
<td>A scale used by the participant (with assistance) to evaluate the quality of their recoveries.</td>
<td>This scale is used to document the quality of the participants’ upset recoveries near the beginning of the Learjet flight and again near the end of the flight, after training has been accomplished. The scale is modeled after the Cooper-Harper rating scale, used worldwide in flight test to assess handling qualities. It considers both performance and workload in establishing a handling quality rating. The Recovery Quality Rating Scale allows the participant to consider both mental and physical workload, apprehension, and confidence, in addition to performance in evaluating the quality of his recoveries.</td>
</tr>
<tr>
<td>Post Flight evaluation of Upset Recovery Training</td>
<td>A document filled out by the participant that documents their evaluation of the course elements.</td>
<td>The evaluation of each course element is entered in the database. Database utilities will be used to informally review the data for trends to assist in course development efforts.</td>
</tr>
</tbody>
</table>
TABLE 2 Description and Purpose of Data Collection Forms.

<table>
<thead>
<tr>
<th>Form</th>
<th>Description</th>
<th>Purpose and Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD ROM - Flight time-history data</td>
<td>The CD ROM records parameters such as attitude, airspeed, altitude, control surfaces, pilot control inputs, and control law values at 100 frames per second.</td>
<td>This time history data is used to verify that the simulation system and control laws are functioning properly. The data is available to assist in the flight debriefing. The data is used to generate a computer display that portrays the motion of the aircraft and the control inputs of the pilot during recoveries. The time history data on the CD and the video on the DVD are retained as source data for further study.</td>
</tr>
<tr>
<td>Beginning Recovery Rating</td>
<td>A self-evaluation, by the participant, using the recovery quality rating scale designed to rate the quality of recoveries near the beginning of the Learjet flight, and before practice on the upset events.</td>
<td>After some familiarization with the handling qualities of the aircraft, the participant is given a few upset events upon which he can base his beginning recovery rating. During these events the Safety Pilot provides only the assistance requested by the participant.</td>
</tr>
<tr>
<td>Ending Recovery Rating</td>
<td>A self-evaluation, by the participant, using the recovery quality rating scale rating the quality of recoveries near the end of the Learjet flight and after practice on the upset events.</td>
<td>After as much practice as possible (given flight time and other constraints) has been accomplished, the participant is given a few upset events, upon which the ending recovery rating is based. During these events the Safety Pilot provides only the assistance requested by the participant.</td>
</tr>
<tr>
<td>Confidence in Rating</td>
<td>This rating is used to express the confidence that the participant has in the beginning and ending ratings.</td>
<td>This rating is used to help future investigators appreciate how much confidence to attach to the ratings.</td>
</tr>
</tbody>
</table>
DESCRIPTION OF THE IN-FLIGHT SIMULATOR LEARJET FLIGHT

The URT protocol is an integrated, multi-part training event. However, the majority of the measures during the first 24-months of the program have focused on the efficacy of the In-Flight Simulator Learjet training flight. To facilitate understanding of the experimental results, a typical Learjet URT demonstration flight is described below.

After level off, at approximately 15,000 feet and 250 Knots Indicated Airspeed (KIAS), the simulation system is engaged which gives control of the simulated aircraft to the participant. The simulation is of a light-to-medium size transport aircraft that is at near max gross weight so that the inertias produce near worst case handling qualities. There are five phases of a typical flight; (1) Familiarization exercises, (2) beginning evaluation exercises, (3) “g” awareness and confidence maneuvers, (4) upset recovery practice events, and (5) ending evaluation exercises. Each of these phases are described below.

FAMILIARIZATION EXERCISES

The first few exercises are designed to familiarize the participant with the handling qualities in the pitch, roll, and yaw axes, and to providing experience in understanding and dealing with the problem presented in the exercise.

Event 1

Center of gravity variations including the following Center of Gravity (CG) positions: (1) normal mid CG, (2) CG too far forward, (3) CG too far aft but stable, and (4) CG too far aft and unstable. The unstable condition is optionally delayed to a later point in the flight as a “beginning” evaluation exercise. The unstable case often gives the participant an opportunity to experience and control a pilot-induced-oscillation (PIO) for
which the traditional methods of recovering from a PIO (releasing the controls, or freezing the controls) does not work.

**Event 2**

Lightly damped dutch roll to provide practice in recovering from a dutch roll using aileron alone, rudder alone, and a combination of aileron and rudder (coordinated and uncoordinated): The participant can experience how the dutch roll grows larger with inappropriate (stepping on the ball) rudder applications, and grows smaller with appropriate (so as to resist the yaw rate) rudder applications. In addition the fact that the inappropriate rudder inputs are the worst case for vertical fin loads, whereas the appropriate rudder inputs produce moderate loads, is stressed. Similarly the participant can experience the advantage of applying aileron and rudder in a cross control manner versus in a coordinated manner. The participant is encouraged to understand the underlying aerodynamic concepts which were brought out in the classroom lectures (dihedral effect, adverse yaw, proverse yaw) to assist in getting the maximum benefit from practicing the various inputs. An underlying goal of this exercise is to provide the participant with exposure to lateral-directional PIOs and experience the types of inputs that exacerbate or minimize the problem.

**Event 3**

Pilot-Induced-Oscillation (PIO) prone aircraft to provide practice in avoiding and recovering from PIO’s: Recovery technique for this stable aircraft case will be contrasted with recoveries from PIOs that result from achieving control of an unstable aircraft.
BEGINNING EVALUATION EXERCISES

At this point the participant will be given several upset events at the nominal difficulty level. The quality, or lack thereof, of the participant’s recoveries will be assessed using the Recovery Quality Rating Scale (RRS). The upset events from which the evaluation events are chosen are the unstable CG, wake turbulence, nose up trim fail, aileron hardover, rudder hardover, nose down trim fail, and complete hydraulic failure. These upset events are described later. Ideally, ratings for each of the beginning evaluation events will be given by the participant (assisted by the safety pilot), and a single overall rating that best describes the results of all of the beginning events taken as a whole. A number of factors, such as proficiency, nausea, time required for familiarization, and natural turbulence, may dictate that the safety pilot may have to depart from the ideal. However, it is highly desired that at least an overall beginning rating be established, even if the confidence in the rating may be low. The confidence (0 to 100%) that the participant and the safety pilot have in the rating is recorded along with the RRS.

“G” AWARENESS AND CONFIDENCE MANEUVERS

Events 4 and 5

Nose high and nose low recoveries with no failures or environmental problems: These are similar to the traditional basic unusual attitude recoveries. Although everyone has practiced these in ground simulators annually, they often prove quite stressful in a real high-performance aircraft. One goal is to give the participant several opportunities to experience “g” levels of .25 g to 2.5 g at airspeeds representative of their line aircraft. In addition experiencing pitch attitudes up to 30 degrees nose high and 25 degrees nose low.
Unloaded pushover and banked recoveries are accomplished for nose high recoveries. Nose low with large bank angle recoveries are accomplished by unloading, rolling to wings level and pulling out at 2.5 g. It is pointed out that this technique expedites the roll to wings level and avoids concerns about structural loads associated with rolling pullouts.

UPSET RECOVERY PRACTICE EVENTS

In all of the following events, the sizes of the upsets are increased as the participant becomes more proficient until a nominal size is achieved. Starting small and building up to a nominal size event provides the most rapid increase in proficiency with the least stress on the stomach. During the practice session the participant is always aware of the type of event that he is about to experience. Random presentation of events is only accomplished after the participant has had sufficient time to practice and evaluate the various techniques that may be used to accomplish the individual events.

Event 6

Wake turbulence: A roll upset that requires measured but large aileron inputs to recover. Measured rudder inputs may improve the recoveries at the larger sizes of upsets.

Event 7

Nose up trim failure: A pitch upset that requires the use of full forward elevator control. Bank may need to be used to stop the nose rise at the larger sizes of upsets. The participant learns to use bank angle to control the pitch attitude instead of elevator control because the elevator needs to be held full forward to prevent an accelerated stall.

Event 8

Aileron hardover: A roll upset that requires large aileron inputs to recover. At larger sizes some rudder is also required. At higher levels of proficiency, the participant
can verify that loading is preferable to unloading, if rudder or asymmetric thrust is being required to control the un-commanded roll. The participant can also observe that increasing airspeed makes the problem worse due to the uncommanded aileron becoming more effective relative to the dihedral effect generated in response to rudder or asymmetric thrust.

**Event 9**

Rudder hardover: A yaw upset that normally elicits a rudder input from the participant. The failure is such that the rudder input has no effect, so the yaw rapidly causes a roll rate due to dihedral effect. The roll must be countered with aileron and at larger size events, unloading assists in controlling the roll until airspeed is increased or asymmetric thrust is applied. At higher levels of proficiency, the participant can experiment with using loading and unloading to control the instantaneous crossover speed.

**Event 10**

Nose down trim failure: A nose down pitch upset that requires full aft elevator control. The participant learns the advantage of raising the nose above the horizon as soon as the nose down problem is recognized. The additional time provided by the nose up attitude allows the participant to consider various options, such as having the other crew member help hold the heavy forces, application of alternate trim, thrust adjustments, or alternate controls such as spoilers, leading edge flaps, trailing edge flaps, and/or landing gear.
Event 11

Complete hydraulic failure: This event fails all three of the primary controls, aileron, elevator, and rudder. Elevator trim is optionally available so the participant can practice controlling the aircraft with and without the use of pitch trim. Participants often have a difficult time recognizing this problem, especially if it is initiated with a slightly out of roll trim, that limits the amount of time they have to solve the problem. So the practice time must be shared between recognizing the problem, and effectively controlling the aircraft after the problem is recognized. This training may be continued after the ending evaluations are accomplished. If conditions permit, the participant may practice a descent and straight in final approach on the return to base.

ENDING EVALUATION EXERCISES

The ending evaluation is similar to the beginning evaluation exercise, except the order and number of the events may be changed. The Beginning and Ending RRSs and a confidence level are recorded on the flight cards, and retained in the participant’s data folder.
RESEARCH QUESTIONS

Our initial research questions were (a) how much did the participant learn from the URT experience, and (b) what elements did the participant find most useful and why? To address these questions, we posed the following specific questions to guide our initial analysis of the data:

- Is there any significant improvement in the Ending over the Beginning RRSs?
- What is the relationship between total flight time and the Beginning RRS?
- What is the relationship between total flight time and the Ending RRS?
- What other factors influence the Beginning RRSs, Ending RRSs, or the magnitude of the difference between them?
  - What effect does military training have on the RRSs?
  - What effect does previous aerobatic experience have on the RRSs?
  - What effect does being an instructor pilot have on the RRSs?
- What are the participant’s perceptions of the URT program?
METHOD

PARTICIPANTS

The participants to date were a total of 294 volunteers recruited by direct contact to airline training departments, website solicitation, and word of mouth. Participants were also informed of the study through numerous articles written about the project and published in aviation journals and trade magazines. Program contact information for participants was often included in the reports.

Data analysis for this report was completed using data sets from 231 qualified air carrier pilots representing 27 different U.S. Part 121 air carriers. The additional participants (not included in these analyses) were from government organizations (e.g., FAA and NTSB), universities, research facilities, and private organizations (e.g. Airline Pilots Association, National Business Aircraft Association, etc). The exclusion of those data facilitated a focused look at the representative air carrier pilot.

Study participants included three females and 228 males. Approximately one-third (88) of the participants had military training. All participants held at least an FAA Commercial pilot certificate with an Instrument Rating, although the majority (199) held an Airline Transport Pilot certificate. All participants maintained a current FAA Medical Certificate. Additional descriptive statistics for the study population is displayed in Table 3. A pictorial representation of the age groups of the participants is shown in Figure 1 and the most represented airlines (those with four or more participants) are shown in Figure 2.
TABLE 3  Mean and Standard Deviations for Participant Demographics.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in Years ( n = 224 )</td>
<td>44</td>
<td>24</td>
<td>67</td>
<td>9.39</td>
</tr>
<tr>
<td>Total Flight Hours ( n = 228 )</td>
<td>10,064</td>
<td>184</td>
<td>31,849</td>
<td>5954</td>
</tr>
<tr>
<td>Hours in Past Year ( n = 227 )</td>
<td>342</td>
<td>00</td>
<td>1,147</td>
<td>271</td>
</tr>
</tbody>
</table>

Age Group

![Age Group Pie Chart](chart.png)

FIGURE 1  Graphic Of Percentage of Participants in Each Age Group.
DATA COLLECTION

Data were collected by the program administrator and Safety Pilots through forms, questionnaires, and instructor notes. All materials containing study materials and data were kept in secure quarters, accessible only to the study principals and researchers.

Data Extraction, Preparation, and Screening

Data Extraction

The multiple sources containing data for analysis (flight time forms, participant demographics, participant postflight evaluations, etc.) were utilized to create a comprehensive database in the Statistical Package for the Social Sciences v. 11.5. All of the necessary variables for analysis were created and data were extracted from the existing sources.
**Data Preparation**

In preparation for data screening, data fields were filled with existing known quantities. Study information of a qualitative nature was coded into categories which were established by high frequencies of common responses. Other continuous data fields were recoded as necessary into categorical variables for data manipulation. For example, the participant age field was recoded into 5 categories where ‘1’ represented participants aged 24 – 30 years. Random checks of the original data sources to the database values for errors in transcription revealed less than .01% errors.

**Data Screening**

All data in this study were next reviewed for accuracy of input into the SPSS file by checking for (a) out-of-range values, (b) plausible means and standard deviations, (c) univariate outliers, and (d) missing data. Pairwise plots for nonlinearity and heteroscedasticity were also reviewed when necessary for the statistical method used. When data was found to be missing, it was random in nature and therefore poses little threat to the validity of the results.

In cases on analysis where Levene's test for equality of variances was found to be significant ($p < .05$), indicating a violation of the assumption of homogeneity of variance, unweighted-means analysis was employed. In most cases, the violation of this assumption was due to unequal cell sizes (unequal $n$’s) and this correction is sufficient as the differences in cell sizes reflects the true nature of the population. The data examined in the following analyses were also tested for skewness and kurtosis and transformations were made, if necessary.
INTER-RATER RELIABILITY

The study was conducted and data was collected by six different instructor pilots (safety pilots). Analyses were conducted and no significant differences were found between Beginning or Ending RRSs from participants of different instructor pilots $F(5, 174) = 1.246, p = .290$. Figure 3 displays the Beginning and Ending RRSs by instructor.

FIGURE 3  Participant Recovery Rating Scores by Each Instructor.
RESULTS

Unless otherwise specified, all analyses were conducted with alpha level set at $p < .05$. Analyses were conducted using the Statistical Package for the Social Sciences v. 11.5. All graphic scales depicting data analysis are scaled identically for ease of comparison.

UPSET RECOVERY RATING SCORE DIFFERENCES

A paired-samples t-test was conducted to evaluate the impact of the in-flight simulator Learjet training on responses the recovery rating scale as displayed in Figure 4. There was a statistically significant decrease (improvement in perceived performance) from the beginning rating scores ($m = 6.27$, $SD = 2.02$) to the ending rating ($m = 2.89$, $SD = 1.15$), $t(179) = 26.59$, $p < .0005$. The eta squared statistic (.80) indicated a very large effect size.

![Graph showing recovery rating score differences](image)

**FIGURE 4** Participant Mean Beginning and Ending RRSs.
EFFECTS OF TOTAL FLIGHT TIME ON UPSET RECOVERY RRS SCORES

A repeated-measures univariate analysis of variance (ANOVA) was conducted to investigate the effects of total flight time on Beginning and Ending RRSs. Preliminary analysis of data was performed to assess the underlying assumptions of normality, linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity. No serious violations of the assumptions were noted. The number of participants per cell was not equal or particularly plentiful, \( n \) ranging from 25 to 35 per cell as displayed in Table 4.

A significant difference was found for the main effect of flight time on the RRSs, \( F(3,173) = 2.77, p < .05 \) with a moderate effect size (partial Eta squared = .05). Estimated marginal means and standard errors were evaluated post-hoc (\textit{a posteriori}) for differences using the Least Significant Differences pairwise multiple comparison test. No significant interaction effects with the dependent variable (RRSs) were found. There were significant differences \((p < .05)\) in the estimated marginal means of the lowest time pilots as compared to each of the other three groups (5,001 – 10,000; 10,001 – 15,000; > 15,000). These results are depicted in Figure 5.

TABLE 4 Mean and Standard Deviations for Participant Flight Time Categories

<table>
<thead>
<tr>
<th>Flight Time (Hours)</th>
<th>( n )</th>
<th>Mean Beginning RRS (SD)</th>
<th>Mean Ending RRS (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5000</td>
<td>37</td>
<td>6.94 (2.23)</td>
<td>3.19 (1.17)</td>
</tr>
<tr>
<td>5,001 – 10,000</td>
<td>55</td>
<td>6.31 (2.03)</td>
<td>2.80 (1.19)</td>
</tr>
<tr>
<td>10,001 – 15,000</td>
<td>51</td>
<td>5.58 (1.81)</td>
<td>2.84 (1.06)</td>
</tr>
<tr>
<td>&gt; 15,000</td>
<td>34</td>
<td>6.23 (2.01)</td>
<td>2.87 (1.14)</td>
</tr>
</tbody>
</table>
FIGURE 5  Participant Mean Beginning and Ending RRSs by Total Flight Time.

EFFECTS OF TYPE OF TRAINING ON UPSET RECOVERY RATING SCORES

A repeated-measures univariate analysis of variance (ANOVA) was conducted to investigate the effects of military training on Beginning and Ending RRSs. Preliminary analysis of data was performed to assess the underlying assumptions of normality, linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity. No serious violations of the assumptions were noted, except for a significant Levene’s statistic ($p < .01$) for the Beginning RRSs. This indicated a lack of homogeneity of variance for this comparison. The number of participants per cell was not equal as displayed in Table 5.

A significant difference was found for the effect of type of training on the RRSs, $F (1,175) = 5.83$, $p < .05$ with a small effect size (partial Eta squared = .03) as shown in Figure 6.
TABLE 5  Mean and Standard Deviations for Different Types of Training

<table>
<thead>
<tr>
<th>Type of Training</th>
<th>n</th>
<th>Mean Beginning RRS (SD)</th>
<th>Mean Ending RRS (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civilian Only</td>
<td>110</td>
<td>6.45 (2.16)</td>
<td>3.05 (1.25)</td>
</tr>
<tr>
<td>Military and Civilian</td>
<td>67</td>
<td>5.89 (1.72)</td>
<td>2.58 (0.85)</td>
</tr>
</tbody>
</table>

FIGURE 6  Mean Beginning and Ending RRSs of Participant by Type of Training.

EFFECTS OF AEROBATIC EXPERIENCE ON UPSET RRS SCORES

A repeated-measures univariate analysis of variance (ANOVA) was conducted to investigate the effects of previous aerobatic training on Beginning and Ending RRSs. No aerobatic training was indicated by “None” while recreational or minimal aerobatic training was designated “Some”. “Extensive” aerobatic training was either (former) military fighter pilots or those who had performed in airshows.
Preliminary analysis of data was performed to assess the underlying assumptions of normality, linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity. A significant Levene’s statistic \( p < .05 \) for the Beginning and Ending RRSs. This indicated a lack of homogeneity of variance for these comparisons, however corrections to the alpha level were made for these analyses. The means and standard deviations for each aerobatic experience group are shown in Table 6.

A significant difference was found for the main effect of previous aerobatic training on the RRSs, \( F (2,174) = 6.55, p = .002 \) with a moderate effect size (partial Eta squared = .07). A graphical representation of the results is displayed in Figure 7. Estimated marginal means and standard errors were evaluated post-hoc for differences using the Least Significant Differences pairwise multiple comparison test. No significant interaction effects with the dependent variable (RRSs) were found. There were significant differences \( p < .005 \) in the estimated marginal means of the pilots with no aerobatic experience, and those with extensive aerobatic experience.

**TABLE 6  Mean and Standard Deviations for Participant by Aerobatic Experience.**

<table>
<thead>
<tr>
<th>Aerobatic Experience</th>
<th>( n )</th>
<th>Mean Beginning RRS (SD)</th>
<th>Mean Ending RRS (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>44</td>
<td>6.84 (2.30)</td>
<td>3.48 (1.49)</td>
</tr>
<tr>
<td>Some</td>
<td>67</td>
<td>6.21 (2.06)</td>
<td>2.82 (1.00)</td>
</tr>
<tr>
<td>Extensive</td>
<td>66</td>
<td>5.88 (1.70)</td>
<td>2.53 (0.83)</td>
</tr>
</tbody>
</table>
FIGURE 7 Mean Beginning and Ending RRSs of Participant by Aerobatics.

EFFECTS OF FLIGHT INSTRUCTING ON UPSET RRS SCORES

A repeated-measures univariate analysis of variance (ANOVA) was conducted to investigate the effects of flight instructing on Beginning and Ending RRSs. Preliminary analysis of data was performed to assess the underlying assumptions of normality, linearity, univariate and multivariate outliers, homogeneity of variance–covariance matrices, and multicollinearity. No serious violations of the assumptions were noted. The means and standard deviations for Beginning and Ending RRSs are shown in Table 7.

No significant difference was found for the effect of flight instructing on the RRSs, $F(1,148) = .317, p = .57$ as shown in Figure 8.
TABLE 7 Mean and Standard Deviations for Flight Instructors and Non-Flight Instructors

<table>
<thead>
<tr>
<th>Flight Instructor</th>
<th>n</th>
<th>Mean Beginning RRS (SD)</th>
<th>Mean Ending RRS (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>49</td>
<td>6.41 (2.20)</td>
<td>2.93 (1.18)</td>
</tr>
<tr>
<td>Yes</td>
<td>101</td>
<td>6.24 (1.99)</td>
<td>2.83 (1.10)</td>
</tr>
</tbody>
</table>

FIGURE 8 Mean Beginning and Ending RRSs of Participant by Flight Instruction.

PARTICIPANTS’ PERCEPTIONS OF THE TRAINING PROGRAM

Participants’ perceptions of the URT program were evaluated through frequency analysis. These results are presented pictorially in Figure 9 through Figure 15. The first graph in the sequence indicates the frequency of responses for the participant’s opinion of the training element (e.g., wake turbulence demonstration). The second graph in the
sequence is the self-reported comment, coded into categories from open-ended questions (simply “comments”) on the course evaluation form. The comment categories were: desired more information, no new information was learned, little new information was learned, review or reinforcement of previous knowledge, some new information was learned, extensive new information was learned, the information was of little or no value, and it was useful information. Figure 16 shows the overall comments from the participants in the study.

In addition, the relative importance of each element of the In-Flight Simulator Learjet flight was determined by rank order (1 = fair to 5 = excellent) of the mean scores from the participants’ course evaluation forms. These scores are presented in Table 8 in order of highest to lowest mean score for the training elements.

**TABLE 8 Mean and Standard Deviations for Participant Ratings of IFS Learjet Course Elements.**

<table>
<thead>
<tr>
<th>Course Element (Recovery)</th>
<th>n</th>
<th>Mean Rating (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rudder Failure Recoveries</td>
<td>201</td>
<td>4.91 (0.30)</td>
</tr>
<tr>
<td>Nose Up Trim Failure Recoveries</td>
<td>202</td>
<td>4.84 (0.40)</td>
</tr>
<tr>
<td>Aileron Failure Recoveries</td>
<td>202</td>
<td>4.84 (0.44)</td>
</tr>
<tr>
<td>Nose Low Recoveries</td>
<td>200</td>
<td>4.83 (0.39)</td>
</tr>
<tr>
<td>Nose High Recoveries</td>
<td>202</td>
<td>4.83 (0.39)</td>
</tr>
<tr>
<td>Center of Gravity Changes</td>
<td>202</td>
<td>4.78 (0.52)</td>
</tr>
<tr>
<td>Nose Down Trim Failure</td>
<td>196</td>
<td>4.77 (0.48)</td>
</tr>
<tr>
<td>Wake Turbulence Recoveries</td>
<td>200</td>
<td>4.77 (0.52)</td>
</tr>
<tr>
<td>Complete Hydraulic Failure Recoveries</td>
<td>201</td>
<td>4.75 (0.58)</td>
</tr>
<tr>
<td>Dutch Roll Recoveries</td>
<td>201</td>
<td>4.73 (0.56)</td>
</tr>
</tbody>
</table>
FIGURE 9 Participant Rankings on Rudder Failure Recoveries.

FIGURE 10 Participant Rankings on Nose High Recoveries.
FIGURE 11 Participant Comments on Nose High Recoveries.

FIGURE 12 Participant Rankings on Aileron Failure Recoveries.
FIGURE 13  Participant Comments on Aileron Failure Recoveries.

FIGURE 14  Participant Rankings on Wake Turbulence Recoveries.
Participant Comments - Wake Turbulence Recoveries

FIGURE 15 Participant Comments on Wake Turbulence Recoveries.

Participants Comments on Overall Course

FIGURE 16 Participant Comments on the Overall Course.
DISCUSSION

Overall, these results suggest a strong positive influence of the Upset Recovery Training Program on a pilot’s ability to respond to an inflight upset. Specifically, the RRS scores indicate a very strong training effect. It is interesting to note the effect of flight times on the Beginning and Ending RRS scores. Even though there is a significant main effect, the bulk of the variance between groups is with the lowest time pilots (< 5000 hours) and those pilots with > 5000 hours. This suggests that pilots of all experience levels (based on total flight time) gain essentially the same benefit from the training.

The effect of military training on the RRS scores is also worth noting. The effect size is particularly small and the majority of the variance was found to be in the beginning scores. Since many civilian pilots have not had the opportunity to perform aerobatics, it is not surprising that there is a significant effect of having experienced aerobatic flight on the RRS scores. Additional analyses were undertaken to determine how much of this effect was confounded by military training. When the effects of aerobatic experience were held constant, there were virtually no differences in the two groups.

The lack of a significant effect of experience as a flight instructor on RRS scores is not particularly surprising. This specialized, advanced airmanship type regimen is not currently taught to flight instructors, therefore it is also not taught by flight instructors (Federal Aviation Administration, 2002). Furthermore, most airline pilots no longer participate in instruction outside of the airline.
Although this adaptation of the Cooper-Harper Scale (RRS) has not been previously validated as a measurement instrument, these results offer some interesting insights into its usefulness. First, the six instructor pilots assisting in the use of the scale found homogeneity in their participants’ Beginning and Ending RRS scores. This suggests that the scale is being used in a consistent manner across all users. Next, the RRS scores follow known trends in pilot expertise research for total flight time (Jensen, 1995), whereas the lower time pilots showed significantly higher Beginning RRS scores than the higher time pilots. Finally, the RRS scores followed the hypothesis that pilots with aerobatic training would have lower RRS scores (better performance) than those without any aerobatic training. Neither the total flight time, nor the aerobatic experience level of the participants was known to the instructor pilots before the training event minimizing experimenter bias. Therefore, one could conclude that the RRS is a valid measure of this task.

The participants’ perceptions of the program appear very positive in these data; however, their scores reflect a ceiling effect on their ratings of the specific course elements.

**Previous Limitations of Current Study**

There were numerous limitations in the current research avenue of this hybrid training-research program which have been progressively countered over the past year. The most salient problems were:

- The study population is self-selected volunteers who in many cases are from the flight training department or management. Even though there were no significant effects of
being a flight instructor, per se, on RRSs, there is still a need for a more representative population to better be able to generalize the results of the study.

- Extraneous variance in the experimental setting and measurement techniques resulting mostly from the nature of aviation (weather, mechanical malfunctions, etc.)
- The testing effect of a repeated measures design without a control or pretest condition.
- Mono-operation bias whereas the focus has been on only one aspect of a multi-part training program. The influence of the academics, Bonanza flight, and ground simulator are not controlled or measured in the current format of the study.
- The use of only one performance measurement technique creates a mono-method bias which only measures one aspect of the construct of training effectiveness.
- The possible unreliability of the RRS where measurement error may occur as it has not been cross-validated or scrutinized as an accurate representation of training effectiveness.
- Experimenter expectancies are not able to be cross-checked by any other measurement tool at this time.

Managing the Threats to Validity

New protocols, forms, and data collection efforts were established and implemented as countermeasures to the threats to validity listed above. These will assist in managing the threats to statistical and internal validity by controlling for, or measuring, the confounding variables. Other initiatives, such as instructor calibration, and collection of more detailed flight time and pilot experience have also been established.
FUTURE DIRECTION AND CONCLUSIONS

As soon as a sufficient number of participants complete the new study protocol, another detailed analysis of the efficacy of the program will be prepared. More exacting pilot demographics and flight times will also allow for control of experience levels. Measurement techniques have been established to specifically test for the training effects at each stage of the training and will be employed with future participants. These enhancements to the research protocol will provide richer data from which the training program will ultimately benefit.
RECOVERY QUALITY RATING SCALE

<table>
<thead>
<tr>
<th>ADEQUACY OF UPSET RECOVERY OR CONFIDENCE MANEUVER</th>
<th>RECOVERY CHARACTERISTICS</th>
<th>DEMANDS ON THE PILOT IN SELECTED RECOVERY OR CONFIDENCE MANEUVER</th>
<th>PILOT RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Excellent Highly desirable Pilot stress/fear not a factor for desired recovery/Maneuver quality, highly confident</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good Good Negligible deficiencies Pilot stress/fear not a factor for desired recovery/Maneuver quality, highly confident</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fair D Some mildly unpleasant deficiencies Minimal pilot stress/fear with desired recovery/Maneuver quality, very confident</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minor but annoying deficiencies Desired recovery/Maneuver quality with moderate pilot stress/fear, moderate confidence</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderately objectionable deficiencies Adequate recovery/Maneuver quality with considerable pilot stress/fear, moderate confidence</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very objectionable but tolerable deficiencies Adequate recovery/Maneuver quality with extensive pilot stress/fear, small confidence</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Major skill / knowledge deficiencies Adequate recovery/Maneuver quality not attainable with maximum tolerable pilot stress/fear, successful outcome is in doubt</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major skill / knowledge deficiencies Intense pilot stress/fear, successful outcome unlikely</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major skill / knowledge deficiencies Intense pilot stress/fear, successful outcome very unlikely</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major skill / knowledge deficiencies Extreme stress/fear, recovery will fail almost always</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>skill / knowledge warrant improvement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>skill / knowledge deficiencies require improvement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Improvement mandatory</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pilot decisions
REFERENCES


