Global Implementation of Upset Prevention & Recovery Training

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Upset Prevention & Recovery Training (UPRT) is rapidly being implemented by airlines worldwide due to regulations requiring this training. UPRT is intended to improve the ability of pilots to develop an awareness of hazards that can lead to upsets, to train pilots on how best to prevent upsets, and to develop recovery skills if awareness and prevention fails. These upsets can include unintended attitude excursions or stalls. This paper will review the requirements for proper UPRT implementation in airlines and discuss some of the issues as airlines start to implement this training into their programs.

I. Introduction – The Need for UPRT in Airline Training

Loss of Control In-Flight (LOC-I) accidents contribute to nearly half of commercial airline fatalities during the past decade. In 2009, the Royal Aeronautical Society created the International Committee for Aviation Training in Extended Envelopes (ICATEE) to determine if common trends existed in these accidents and to recommend suitable training remedies. The recommendations made by ICATEE were integrated into the ICAO Manual of Aeroplane Upset Prevention and Recovery Training (ICAO Manual 10011). These include training requirements for both initial and recurrent training of airline pilots, covering academic and practical training.

Furthermore, the Federal Aviation Administration has mandated UPRT for all Part 121 carriers, and the European Aviation Safety Agency (EASA) is in the process of adopting its own requirements for European airlines, as well as for cadet-level training programs.

Prior to the introduction of UPRT, training schools and airlines offered “Unusual Attitude” training, which essentially placed the student into an extreme orientation and required pilots to recover. However, as ICATEE’s deliberations pointed out, two elements were missing: The prevention of these attitudes in the first place, and the psychophysical or “startle” reaction by the pilot that could influence their decision making. UPRT attempts to integrate these two elements into a consolidated training process.

Both regulation and an impetus to maintain high safety levels are driving airlines to rapidly deploy UPRT. However, some airlines have also had recent upset-related events, and are embarking on safety enhancement programs involving UPRT. For example, an All Nippon Airways Boeing 737 encountered an overbank upset during a routine flight, due to an inadvertent rudder trim application by a pilot. A Chinese operator encountered a stall in an Airbus A320 during an approach in severe weather. AirAsia encountered a fatal A320 LOC-I accident in 2014.

Another major airline (anonymous) reported the following safety-related events during a recent period of two years, based on objective data, indicating the importance of this enhanced training:

<table>
<thead>
<tr>
<th>Event</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stall Warning</td>
<td>68</td>
</tr>
<tr>
<td>Overspeed</td>
<td>995</td>
</tr>
<tr>
<td>Bank-angle exceedance</td>
<td>232</td>
</tr>
<tr>
<td>GPWS Windshear / Sink Rate</td>
<td>57 / 124</td>
</tr>
<tr>
<td>Automation Handling</td>
<td>31</td>
</tr>
<tr>
<td>Tail strikes</td>
<td>3</td>
</tr>
</tbody>
</table>

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II. ICATEE Recommendations

The ICATEE working group developed recommendations for both the training components and their implementation. In order to define the training requirements, a task analysis was carried out by considering all of the learning elements required for both upset prevention and for recovery. In total, 176 learning elements were defined in this task analysis, covering four levels of mitigation:

a) Awareness (developing an understanding of the causal factors of upsets)
b) Recognition (early detection of conditions that could cause an upset)
c) Avoidance (immediate intervention to prevent further escalation of an upset)
d) Recovery (exercising of techniques to recover from a developed upset and re-stabilize the flight path)

Note that a), b) and c) are considered “prevention” mitigations, requiring both an adequate level of academic knowledge and the ability to recognize upset-related threats in a type-specific environment. The objective is to develop the requisite knowledge and skills as early as possible in a pilot’s career, and to maintain them throughout (during recurrent training). Consideration must also be given to filling the training gap for the existing population of pilots through specialized training sessions. This will be discussed in Section V.

ICATEE’s training matrix was then coupled to possible training media, including academic knowledge, current-generation flight simulators, enhanced simulators, specialized training devices (e.g., disorientation or continuous-g trainers), and aerobatic-capable aircraft. The summary of ICATEE’s recommended training footprint is shown in Table 1.

ICATEE’s task analysis determined that 56 percent of the training footprint could be covered by knowledge and with better use of today’s Level D / Type 7 simulators, without modification. With enhancements to these devices (instructor station feedback, better matching of stall-related buffet and validated post-stall aero modelling), nearly 85% of the training requirements could be achieved. This would cover the recovery portion as well.

<table>
<thead>
<tr>
<th>Device</th>
<th>Awareness</th>
<th>Prevention</th>
<th>Recovery</th>
<th>Total Tasks</th>
<th>% Total Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training Tasks that Use Existing ICAO-Approved Simulation Devices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (Academic only)</td>
<td>8</td>
<td>13</td>
<td>33</td>
<td>54</td>
<td>30.7%</td>
</tr>
<tr>
<td>Type III</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>3.4%</td>
</tr>
<tr>
<td>Type V</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>4.5%</td>
</tr>
<tr>
<td>Type VII</td>
<td>1</td>
<td>11</td>
<td>19</td>
<td>31</td>
<td>17.6%</td>
</tr>
<tr>
<td>Subtotals</td>
<td>12</td>
<td>29</td>
<td>58</td>
<td>99</td>
<td>56.3%</td>
</tr>
<tr>
<td>Training Tasks that Use Non-Existent or Non-ICAO Approved Simulation Devices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgraded Type VII+</td>
<td>7</td>
<td>22</td>
<td>17</td>
<td>46</td>
<td>26.1%</td>
</tr>
<tr>
<td>Spin Training Device</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>4.5%</td>
</tr>
<tr>
<td>G Awareness Device</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>10</td>
<td>5.7%</td>
</tr>
<tr>
<td>Spatial Disorient. Device</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.1%</td>
</tr>
<tr>
<td>Aeroplane</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>11</td>
<td>6.3%</td>
</tr>
<tr>
<td>Subtotals</td>
<td>17</td>
<td>30</td>
<td>30</td>
<td>77</td>
<td>43.7%</td>
</tr>
<tr>
<td>Summary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>

Task Totals 29 59 88 176 100.0
III. Current Regulations Governing UPRT

ICAO 10011 is referenced in ICAO Annex 1,\textsuperscript{viii} Annex 6,\textsuperscript{xiii} and PANS-TRG,\textsuperscript{xv} which applies to Multi-Crew Pilot License (MPL) training requirements.

The FAA has issued Part 121.423,\textsuperscript{x} AC 120-109,\textsuperscript{x} AC 120-109A,\textsuperscript{x} and AC 120-111\textsuperscript{xvi} to deal with the requirements for UPRT, including post-stall training in simulators. These followed the Congressional mandate and Public Law 111-216 Sec 208, Implementation of NTSB Flight Crewmember Training Recommendations, signed by President Obama in 2010.

EASA issued in May 2015 additional acceptable means of compliance and guidance material for UPRT during operator conversion and recurrent training programs in ORO.FC.220 and ORO.FC.230, respectively, of the EU Air Operations Regulations.\textsuperscript{xv} Operators in Europe must comply with this UPRT by May 2016 as required by the corresponding ED Decision 2015/012/R. For the licensing level and instructor qualification requirements, additional draft EASA materials are currently under review, including the use of aircraft to train pilots at CPL/MPL levels, and for instructor training. For the purpose of global harmonization, hopefully the final EASA regulations will be harmonized with the FAA rules for UPRT.

IV. Training Requirements for Effective UPRT

A. Academic Knowledge

Understanding the causes of upsets, case studies on past upset events/accidents, and aerodynamic knowledge on proper mitigation and recovery strategies is paramount. Airplane upsets are defined as unintentionally exceeding pitch attitudes of +20 or -10 deg, bank angles beyond ±45 deg, or flight at inappropriate speed for the given configuration.\textsuperscript{xv} Possible causes are indicated below.

\begin{center}
\begin{tabular}{|l|l|l|}
\hline
\textbf{Environmental} & \textbf{System Anomaly} & \textbf{Pilot Induced} \\
Wake vortex & Flight Instruments & Inappropriate use of autopilot \\
Clear Air Turbulence & Autopilot & Piloting technique \\
Mountain Wave & Flight Control System & Incapacitation \\
Thunderstorm & & Spatial Disorientation \\
Icing & & Distraction \\
Microburst & & Inattention \\
\hline
\end{tabular}
\end{center}

The primary resource for pilot knowledge is the Aeroplane Upset Recovery Training Aid (AURTA), which defines most of the necessary knowledge that pertains to operating transport aircraft. An update of this manual is expected in 2016.

B. Practical Training

For most pilots, the Flight Simulation Training Device (FSTD) will remain the most valuable asset in the development and checking of skills related to UPRT. As indicated in Table 1, existing Level D FSTD’s can provide 25.5\% of the required training. When combined with the aforementioned academic training, 56\% of the training need is covered.

However, a key aspect of the training is not just the content but also the delivery. In order to adequately prepare air crews to deal with upsets, both a maneuver-oriented (training to proficiency), and a scenario-based approach is recommended. Maneuver-oriented training or instructor-led demonstrations allow a candidate to experience the levels of escalation in a particular aircraft type when the simulation supports the required capabilities. The familiarization with the warnings and the envelope protection features of the particular aircraft develops awareness.

Scenario-based training is intended to create realistic conditions in which upsets could occur. Several means have been devised to distract the student and create a level of surprise in the simulator, and to induce upsets due to external factors, such as wake vortices or rapid atmospheric changes (wind, air temperature, air pressure).

\textbf{Stall Demonstrations in FSTD’s}

Stalls have proven to be a major contributor in airplane upsets, possibly due to their unpredictable nature or the challenges that they pose: the “roll off” could cause the pilot to be distracted and to counteract the roll while stalled.
through aileron inputs, as occurred in the Colgan 3407 crash in 2009\textsuperscript{vii}. In fact, the sole action should be to reduce the angle of attack, followed by rolling the wings to level and stabilization of the flight path.

The FAA has introduced mandatory stall prevention and recovery training in FSTD’s. Guidance material indicates that the aircraft manufacturer’s stall recovery procedures shall be applied and, if consultation with the manufacturer is impractical, the following stall recovery template should be executed\textsuperscript{xii}:

1. Autopilot and auto throttle.........................................................Disconnect
2. a) Nose down pitch control...............................Apply until stall warning is eliminated
   b) Nose down pitch trim..................................................As Needed
3. Bank............................................................................Wings Level
4. Thrust ...........................................................................As Needed
5. Speed brakes/Spoilers........................................................Retract
6. Return to the desired flight path.

In the FAA Advisory Circular 120-109A, clear guidance is given regarding the instructor’s role, objective, emphasis areas, proper FSTD setup, scenario elements, completion standards and common pilot/instructor errors.

**FSTD Enhancements**

While current FSTD’s may be suitable for the training of upset prevention, modifications may be required in order to make these devices suitable for operation outside their operational flight envelopes from which recoveries must be exercised. First, it is important to know that the upset definition does not mean that a simulation model is outside its validated envelope during every upset. However, additional modeling or validation of the aircraft model may be required in the proximity of the stall, or other parts of the flight envelope. Near the stall, transport aircraft may demonstrate deterrent buffet, reduced control effectiveness, reduced damping, Mach effects, rapid and possibly uncommanded departures from the flight path, activation of stall warning/stick shaker, activation of envelope protection/stick pusher, or any combination thereof. These are covered by the FAR CFR Part 60\textsuperscript{xvii}.

Validation criteria utilizing both objective and subjective means were proposed by ICATEE.\textsuperscript{xviii} In the pre-stall regime, more stringent requirements are proposed, while the post-stall area may utilize “type representative” flight models. This data can be derived from flight tests, wind tunnels or computational sources.

Enhanced data will include stall characteristics, response of the aircraft to gusting crosswinds, bounced landings, and icing effects. For regulatory qualification, airframe manufacturers will also need to provide the simulator validated envelope, stall characteristics objective tests, and a UPRT Statement of Compliance.

An additional enhancement, also recommended for existing simulators, is instructor feedback during the upset event. This can impart improved monitoring during the upset event and debrief of the crew’s performance. Although properly-designed and executed scenarios can reduce the risk of the simulator exceeding its fidelity envelope, which could otherwise lead to negative training, real-time monitoring can help the instructor ensure that the skills exercised during the recovery could be transferred to the actual environment. Secondly, the pilot must exercise appropriate control inputs and, for example, avoid rapid rudder movements that could overstress part of the airframe.

The information typically helpful on a UPRT-capable FSTD instructor station is illustrated in Figure 1. For all FSTD requirements, see ICAO 9625\textsuperscript{ix}.

![Figure 1. UPRT Instructor Feedback Information. Clockwise from top-left: Alpha-Beta envelope, with data validity levels (flight-test validated (green), estimated high-confidence (yellow), estimated lower-confidence (red)); V-n diagram; Primary Flight Display; Control Inputs and Airplane Configuration.](image-url)
On-Aircraft Training

The use of single-engine piston aircraft for UPRT has grown rapidly. FSTD limitations can render them incapable of providing the complete exposure to LOC-I recoveries: motion cueing limitations and the possible reduced emotional response can introduce boundaries that prevent pilots from experiencing the full range of airplane attitudes, load factors, and flight behavior. Unlike an FSTD, in an airplane, the aerodynamics are real, and loads resulting from maneuvering are not scaled. On-aircraft UPRT is not however intended to demonstrate aircraft-specific characteristics or performance, but to introduce the general principles and techniques that may be applied over a wide range of commercial transport aircraft.

On-aircraft UPRT is distinctly different from aerobatic flight. While the latter improves manual handling skills, UPRT does not focus on the reproduction of planned, precise maneuvers, but the restoration of the aircraft to a stable flight condition. Furthermore, aerobatic flight does not focus on the analytical reasoning skills required to rapidly and accurately recover the aircraft during periods of high stress.

On-aircraft UPRT is not mandated by the FAA; however it is required by EASA for MPL licensing and recommended under CPL courses. It is also being applied “ad hoc” for the development of simulator UPRT instructor competencies (see Section VI).

V. Airline Implementation of UPRT

Application of UPRT

While standards have been established by ICAO, the FAA and EASA to being UPRT in 2016 or beyond, some airlines have opted to implement UPRT early. However, there are also limitations, due to the limited availability of qualified instructors, and valid simulator data. Furthermore, modifications to simulators can require considerable capital investments, which must be weighed by the airlines. This section is intended to give insight into the early practices taking place by several airlines. While specific names are not mentioned, the purpose here is to illustrate how UPRT has been put into practice to date.

Instructor Qualification and Standardization

ICAO states that “there are specific risks associated with UPRT, which demand that the training be effectively managed by the applicable quality assurance and safety management related practices of the training provider.” Airline flight instructors may encounter the same deficiencies as line pilots, when it comes to UPRT. Daily operations seldom bring the aircraft towards the edge of the envelope, making pilots and instructors unprepared for these situations without proper training. Furthermore, to effectively evaluate line pilots, and to provide feedback, instructor pilots often undergo additional qualification programs that integrate academic and practical training. In some cases, additional on-aircraft training is provided to these instructors to develop better awareness of recovery strategies, awareness of dynamic maneuvers, and management of startle response.

UPRT Exercises

The execution of UPRT in an airline environment is aimed at developing an understanding of aerodynamic principles, and applying these in a timely manner if needed. Typically, airlines will dedicate a complete session to UPRT in order to disseminate the knowledge and develop a baseline of skills amongst its pilots. This is followed by revisiting the UPRT exercises throughout the recurrent training sessions that the pilots regularly undertake as part of their career.

The UPRT elements and components of an airline training program will include the following:

A. Aerodynamics
B. Causes and contributing factors of upsets
C. Safety Review of Accidents and Incidents relating to Airplane Upsets
D. Energy Management
E. Flight Path Management
F. Recognition
G. Upset Prevention & Recovery Techniques
H. System Malfunction
I. Specialized Training Elements (including recoveries from various conditions)
J. Human Factors (Situation Awareness, Startle, Threat & Error Management, Crew Resource Management
UPRT Scenarios
While there are several creative scenarios possible with which one can develop and exercise UPRT-related skills, a few are pointed out herein that are considered valuable training exercises. Note: Exercises must be built up systematically, beginning with basic awareness and recognition exercises, maneuver-based familiarization, and followed by the more complex, integrated exercises, often requiring consolidated recoveries.

Pitch Runaway During Take-Off
As the airplane lifts off, its pitch continues to trim aft, creating an uncontrollable nose-up pitching moment. The objective of the student is to recognize and prevent a stall, and utilize their knowledge of flight mechanics. A suitable recovery involves pointing the lift vector off the vertical by rolling the aircraft and maintaining a constant bank angle that produces stable, turning flight. Thereafter, the pitch trim situation may be diagnosed and resolved.

Nose-Low Stall
The simulator is initiated with a nose-down attitude, while the airspeed is below the stall speed. The objective is to recognize that the critical angle-of-attack is usually independent of the aircraft pitch attitude, and to apply additional nose-down pitch input prior to recovering. For this and other stall exercises, validated stall models are required.

High-Altitude TCAS alert
During maximum-performance high-altitude cruise, a traffic warning is given, requiring the crew to climb. The purpose of the exercise is to demonstrate the sensitivity of the aircraft to control inputs at these altitudes, the danger of entering an accelerated stall due to slight additional g-loading, and the importance of monitoring to prevent such occurrences whenever possible.

Inadvertent Stall Warning (e.g., Stick Shaker)
While extremely unlikely, a false stall warning, such as the false triggering of the stick shaker during initial climb, requires the pilot to confirm the situation, and make quick decisions, which may include “do nothing.”

Recovery from Overbank
The intention of a recovery-from-overbank maneuver is to avoid the tendency of pilots to “pull” in such conditions, which could yield an accelerated stall. The first priority in the overbank is therefore to reduce the wing loading prior to restoring the lift vector to the vertical direction, followed by recovery of the pitch attitude and stabilization of the flight path.

Unreliable Airspeed
Several methods have been devised to train the recognition of unreliable airspeed, a contributing factor in the Air France 447 accident in 2009\textsuperscript{xiii}. The key objective is to maintain basic flying skills (pitch and power for the given configuration), even when primary indications fail.

Power-off Stall Event
As demonstrated in some accidents, pilots may tend to try to power out of a stall event\textsuperscript{xiii}. However, this can exacerbate the situation, due to the powerful nose-up pitching moment applied to the aircraft in a low energy state. Hence, learning to exchange altitude (potential energy) for airspeed (kinetic energy) is a valuable lesson.

Startle
An FAA experiment\textsuperscript{xiv} demonstrated that a crew may be drawn to a specific expectation in an exercise by the instructor, thereby opening an opportunity to create some level of surprise due to an unexpected event elsewhere. In this experiment, the crews were given a strong unexpected wind shear, requiring the immediate execution of the stall recovery procedure. However, since the event was unknown to each crew, it was considered a “surprise.”

In reality, pilots may encounter abnormal events, not only related to the prevention of or recovery from upsets. Casner\textsuperscript{xvii} indicates the value of avoiding rote exercises that result in memorized skills. Ultimately, the prevention of upsets is the highest priority in ensuring safe flight. Integrating pilot knowledge, skills, attitudes and co-ordination between crew members is necessary.
VI. Conclusion

Upset Prevention and Recovery Training (UPRT) will soon be mandated in the United States, Europe and several regions. Airlines are rapidly developing training programs aligned with the guidance materials available today. The proper integration of academic and practical skills is essential in order to practice UPRT and validate proper prevention and recovery skills. It is most important that airlines apply UPRT in a safe manner, by consulting with the airframe manufacturer, developing knowledge on the applicable regulations, and adequately training their instructors to conduct UPRT effectively and with minimum chance of instilling potentially dangerous habits in their pilots. UPRT will continue to enhance pilot awareness, increase confidence, and improve aviation safety.

VII. References

17. FAR CFR PART 60 “FLIGHT SIMULATION TRAINING DEVICE INITIAL AND CONTINUING QUALIFICATION AND USE”. Dept. of Transportation, Dec. 2015

American Institute of Aeronautics and Astronautics