Docket No. SA-522

Exhibit No. 2-Q

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Attachment V
Excerpts from the Boeing/Airbus Training Aid

(31 Pages)

Pilot Guide to Airplane Upset Recovery

2.0 Introduction

The "Pilot Guide to Airplane Upset Recovery" is one part of the *Airplane Upset Recovery Training Aid*. The other parts include an "Overview for Management" (Sec. 1), "Example Airplane Upset Recovery Training Program" (Sec. 3), "References for Additional Information" (Sec. 4), and a two-part video.

The goal of this training aid is to increase the ability of pilots to *recognize and avoid* situations that can lead to airplane upsets and to improve their ability to recover control of an airplane that has exceeded the normal flight regime. This will be accomplished by increasing awareness of potential upset situations and knowledge of aerodynamics and by application of this knowledge during simulator training scenarios.

The education material and the recommendations provided in the *Airplane Upset Recovery Training Aid* were developed through an extensive review process to achieve a consensus of the air transport industry.

2.1 Objectives

The objectives of the "Pilot Guide to Airplane Upset Recovery" are to provide pilots with

- Knowledge to recognize situations that may lead to airplane upsets so that they may be prevented.
- Basic airplane aerodynamic information.
- Airplane flight maneuvering information and techniques for recovering airplanes that have been upset.

It is intended that this information be provided to pilots during academic training and that it be retained for future use.

2.2 Definition of Airplane Upset

Research and discussions within the commercial aviation industry indicated that it was necessary to establish a descriptive term and definition in order to develop this training aid. Terms such as "unusual attitude," "advanced maneuver," "selected event," "loss of control," "airplane upset," and others are terms used within the industry. The team decided that "airplane upset" was appropriate for this training aid. An airplane upset is defined as an airplane in flight unintentionally exceeding the parameters normally experienced in line operations or training.

While specific values may vary among airplane models, the following unintentional conditions generally describe an airplane upset:

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

2

2.4.1.1.5 Microbursts

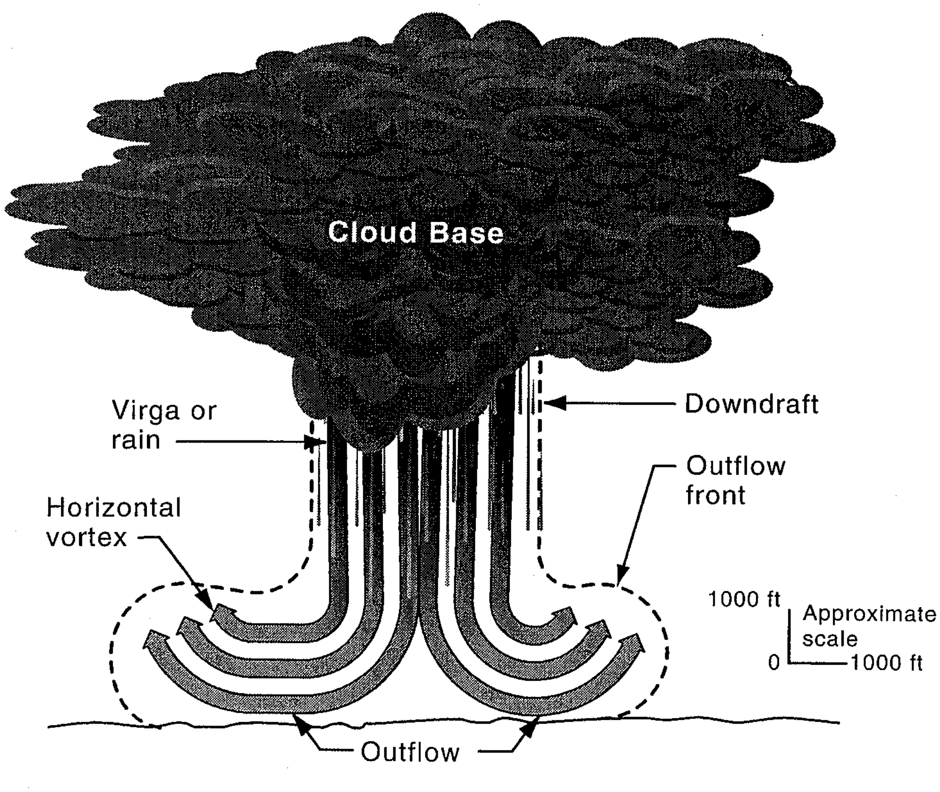
Identification of concentrated, more powerful downdrafts—known as microbursts—has resulted from the investigation of windshear accidents and from meteorological research. Microbursts can occur anywhere convective weather conditions occur. Observations suggest that approximately 5% of all thunderstorms produce a microburst. Downdrafts associated with microbursts are typically only a few hundred to 3000 ft across. When a downdraft reaches the ground, it spreads out horizontally and may form one or more horizontal vortex rings around the downdraft (Fig. 6). Microburst outflows are not always symmetric. Therefore, a significant airspeed increase may not occur upon entering outflows, or it may be much less than the subsequent airspeed loss experienced when exiting the microburst. Windspeeds intensify for about 5 min after a microburst initially contacts the ground and typically dissipate within 10 to 20 min after ground contact.

It is vital to recognize that some microbursts cannot be successfully escaped with any known techniques.

2.4.1.2 Wake Turbulence

Wake turbulence is the leading cause of airplane upsets that are induced by the environment. The phenomenon that creates wake turbulence results from the forces that lift the airplane. High-pressure air from the lower surface of the wings flows around the wingtips to the lower pressure region above the wings. A pair of counter-rotating vorti-

Figure 6 Symmetric Microburst—An airplane transiting the microburst would experience equal headwinds and tailwinds.



3

ces are thus shed from the wings: the right wing vortex rotates counterclockwise, and the left wing vortex rotates clockwise (Fig. 7). The region of rotating air behind the airplane is where wake turbulence occurs. The strength of the turbulence is determined predominantly by the weight, wingspan, and speed of the airplane. Generally, vortices descend at an initial rate of about 300 to 500 ft/min for about 30 sec. The descent rate decreases and eventually approaches zero at between 500 and 900 ft below the flight path. Flying at or above the flight path provides the best method for avoidance. Maintaining a vertical separation of at least 1000 ft when crossing below the preceding aircraft may be considered safe. This vertical motion is illustrated in Figure 8. Refer to the *Wake Turbulence Training Aid* for comprehensive information on how to avoid wake turbulence. This aid is available from the National Technical Information Service or The Boeing Company.

An encounter with wake turbulence usually results in induced rolling or pitch moments; however, in rare instances an encounter could cause structural damage to the airplane. In more than one instance, pilots have described an encounter to be like "hitting a wall." The dynamic forces of the vortex can exceed the roll or pitch capability of the airplane to overcome these forces. During test programs, the wake was approached from all directions to evaluate the effect of encounter direction on response. One item was common to all encounters: without a concerted effort by the pilot to reenter the wake, the airplane would be expelled from the wake and an airplane upset could occur.

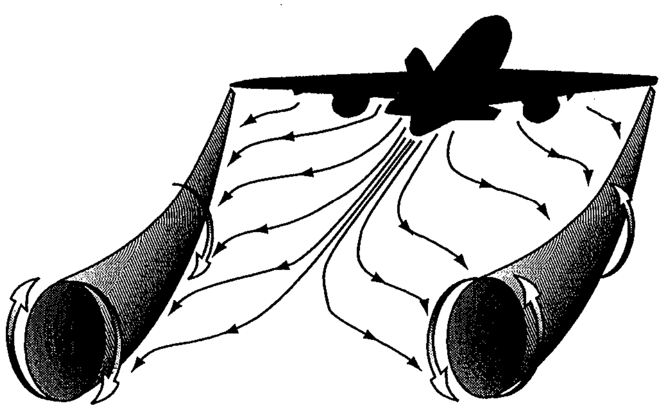


Figure 7
Wake Turbulence Formation

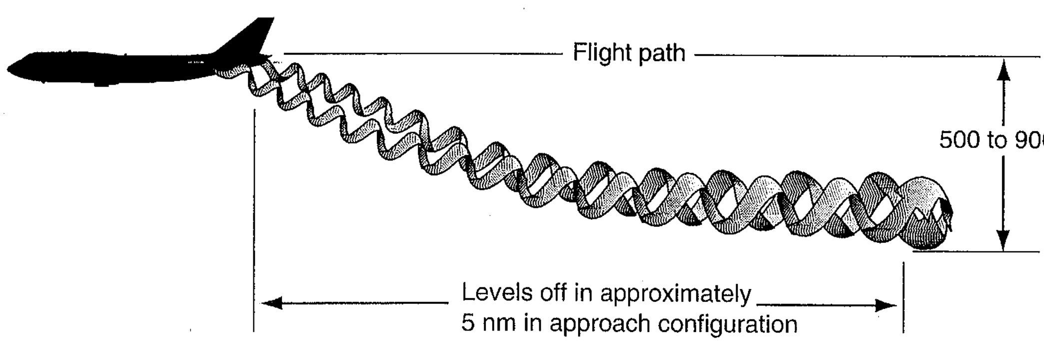


Figure 8
Vertical Motion Out of Ground Effect

4

Counter-control is usually effective and induced roll is minimal in cases where the wingspan and ailerons of the encountering airplane extend beyond the rotational flowfield of the vortex (Fig. 9). It is more difficult for airplanes with short wingspan (relative to the generating airplane) to counter the imposed roll induced by the vortex flow.

Avoiding wake turbulence is the key to avoiding many airplane upsets. Pilot and air traffic control procedures and standards are designed to accomplish this goal, but as the aviation industry expands, the probability of an encounter also increases.

2.4.1.3 Airplane Icing

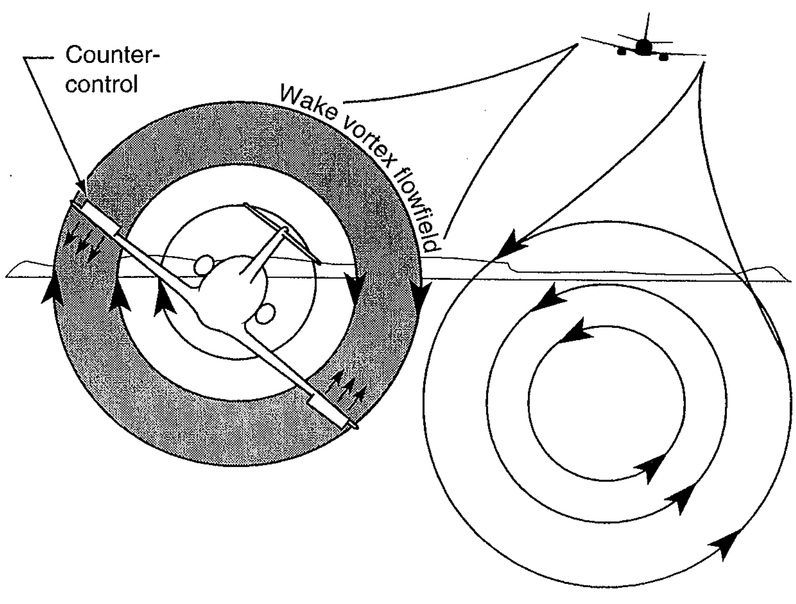
Technical literature is rich with data showing the adverse aerodynamic effects of airfoil contamination. Large degradation of airplane performance can result from the surface roughness of an extremely small amount of contamination. These detrimental effects vary with the location and roughness, and they produce unexpected airplane handling characteristics, including degradation of maximum lift capability, increased drag, and possibly unanticipated changes in stability and control. Therefore, the axiom of "Keep it clean" for critical airplane surfaces continues to be a universal requirement.

2.4.2 Systems-Anomalies-Induced Airplane Upsets

Airplane designs, equipment reliability, and flight crew training have all improved since the Wright brothers' first powered flight. Airplane certification processes and oversight are rigorous. Airlines and manufacturers closely monitor equipment failure rates for possible redesign of airplane parts or modification of maintenance procedures. Dissemination of information is rapid if problems are detected. Improvement in airplane designs and equipment components has always been a major focus in the aviation industry. In spite of this continuing effort, there are still failures. Some of these failures can lead to an airplane upset. That is why flight crews are trained to overcome or mitigate the impact of the failures. Most failures are survivable if correct responses are made by the flight crew.

An airplane was approaching an airfield and appeared to break off to the right for a left downwind to the opposite runway. On downwind at approximately 1500 ft, the airplane pitched up to nearly 60 deg and climbed to an altitude of nearly 4500 ft, with the airspeed deteriorating to almost 0 kn. The airplane then tail-slid, pitched down, and seemingly recovered. However, it continued into another steep pitchup of 70 deg. This time as it

Figure 9
Induced Roll



5

in such a way as to get the aerodynamics of the tab to hold the elevator in the desired position. The airplane is then in trim (because the required load on the tail has been achieved) and the column force trim condition is met as well (because the tab holds the elevator in the desired position). One side effect of this configuration is that when trimmed near one end of the deflection range, there is not much more control available for maneuvering in that direction (Fig. 24).

In the case of the all-flying tail, the entire stabilizer moves as one unit in response to column commands. This changing of the angle of attack of the stabilizer adjusts the tail lift as required to balance the moments. The tail is then held in the desired position by an irreversible flight control system (usually hydraulic). This configuration requires a very powerful and fast-acting control system to move the entire tail in response to pilot inputs, but it has been used quite successfully on commercial jet transport airplanes.

In the case of the trimmable stabilizer, the proper pitching moment is achieved by deflecting the elevator and generating the required lift on the tail. The stabilizer is then moved (changing its angle of attack) until the required tail lift is generated by the stabilizer with the elevator essentially at zero deflection. A side effect of this configuration is that from the trimmed condition, full elevator deflection is available in either direction, allowing a much larger range of maneuvering capability. This is the configuration found on most high-performance airplanes that must operate through a very wide speed range and that use very powerful high-lift devices (flaps) on the wing.

Knowing that in the trimmed condition the elevator is nearly faired or at zero deflection, the pilot instantly knows how much control power is available in either direction. This is a powerful tactile cue, and it gives the pilot freedom to maneuver without the danger of becoming too close to surface stops.

2.5.5.4 Lateral and Directional Aerodynamic Considerations

Aerodynamically, anti-symmetric flight, or flight in sideslip can be quite complex. The forces and moments generated by the sideslip can affect motion in all three axes of the airplane. As will be seen, sideslip can generate strong aerodynamic rolling moments as well as yawing moments. In particular the magnitude of the coupled roll-due-to-sideslip is determined by several factors.

2.5.5.4.1 Angle of Sideslip

Just as airplane angle of attack is the angle between the longitudinal axis of the airplane and the relative wind as seen in a profile view, the sideslip angle is the angle between the longitudinal axis of the airplane and the relative wind, seen this time in the plan view (Fig. 25). It is a measure of whether the airplane is flying straight into the relative wind.

With the exception of crosswind landing considerations requiring pilot-commanded sideslip, commercial transport airplanes are typically flown at or very near zero sideslip. This usually results in the lowest cruise drag and is most comfortable for passengers, as the sideways forces are minimized.

For those cases in which the pilot commands a sideslip, the aerodynamic picture becomes a bit more complex. Figure 25 depicts an airplane in a

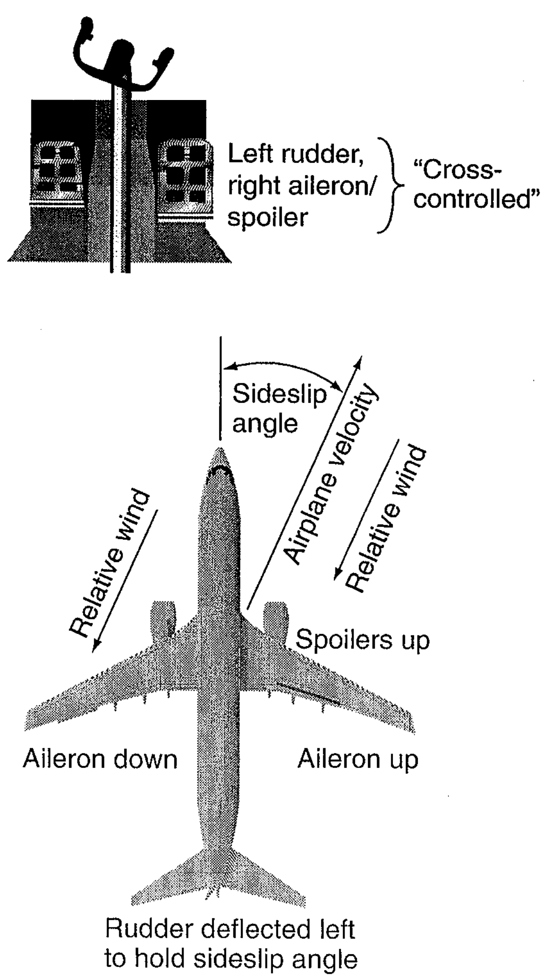


Figure 25
Angle of Sideslip

commanded nose-left sideslip. That is, the velocity vector is not aligned with the longitudinal axis of the airplane, and the relative wind is coming from the pilot's right.

One purpose of the vertical tail is to keep the nose of the airplane "pointed into the wind," or make the tail follow the nose. When a sideslip angle is developed, the vertical tail is at an angle of attack and generates "lift" that points sideways, tending to return the airplane to zero sideslip. Commercial jet transport airplanes are certificated to exhibit static directional stability that tends to return the airplane to zero sideslip when controls are released or returned to a neutral position. In order to hold a sideslip condition, the pilot must hold the rudder in a deflected position (assuming symmetrical thrust).

2.5.5.4.2 Wing Dihedral Effects

Dihedral is the positive angle formed between the lateral axis of an airplane and a line that passes through the center of the wing, as depicted in Figure 26. Dihedral contributes to the lateral stability of an airplane, and commercial jet transport airplanes are certificated to exhibit static lateral stability. A wing with dihedral will develop stable rolling moments with sideslip. If the relative wind comes from the side, the wing into the wind is subject to an increase in lift. The wing away from the wind is subject to a decrease in angle of attack and develops a decrease in lift. The changes in lift effect a rolling moment, tending to raise the windward wing; hence, dihedral contributes a stable roll due to sideslip. Since wing dihedral is so powerful in producing lateral stability, it is used as a "common denominator term" of the lateral stability contribution of other airplane components, such as rudder and wing sweep. In other words, the term "dihedral effect" is used when describing the effects of wing sweep and rudder on lateral stability and control.

A swept-wing design used on jet transport airplanes is beneficial for high-speed flight, since higher flight speeds may be obtained before components of speed perpendicular to the leading edge produce critical conditions on the wing. In other words, wing sweep will delay the onset of compressibility effects. This wing sweep also contributes to the dihedral effect. When the swept-wing airplane is placed in a sideslip, the wing into the wind experiences an increase in lift, since the effective sweep is less, and the wing away from the wind produces less lift, since the effective sweep is greater (Fig. 25). The amount of contribution, or dihedral effect, depends on the amount of sweepback and lift coefficient of the wing. The effect becomes greater with increasing lift coefficient and wing sweep. The lift coefficient will increase with increasing angle of attack up to the critical angle. This means that any sideslip results in more rolling moment on a swept-wing airplane than on a straight-wing airplane. Lateral controls on swept-wing airplanes are powerful enough to control large sideslip angles at operational speeds.

Rudder input produces sideslip and contributes to the dihedral effect. The effect is proportional to the angle of sideslip. (That is, roll increases with sideslip angle; therefore, roll increases with increasing rudder input.) When an airplane is at a high angle of attack, aileron and spoiler roll controls become less effective. At the stall angle of attack, the rudder is still effective; therefore, it can produce large sideslip angles, which in turn produces roll because of the dihedral effect.

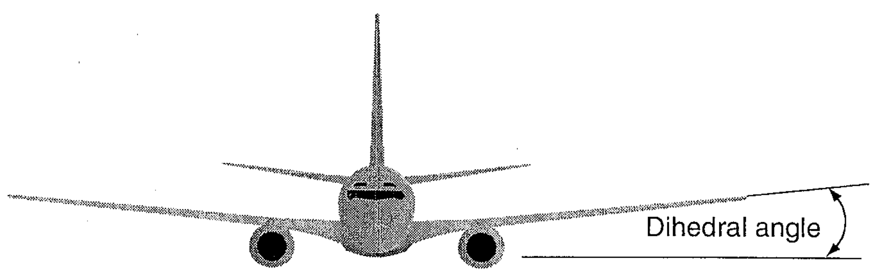


Figure 26
Wing Dihedral Angle

7

2.5.5.4.3 Pilot-Commanded Sideslip

It is important to keep in mind that the rudders on modern jet transport airplanes are usually sized to counter the yawing moment associated with an engine failure at very low takeoff speeds. This very powerful rudder is also capable of generating large sideslips (when an engine is not failed). The large sideslip angles generate large rolling moments that require significant lateral control input to stop the airplane from rolling. In maneuvering the airplane, if a crosswind takeoff or landing is not involved and an engine is not failed, keeping the sideslip as close to zero as possible ensures that the maximum amount of lateral control is available for maneuvering. This requires coordinated use of both aileron/spoilers and rudder in all maneuvering.

One way to determine the sideslip state of the airplane is to "feel" the lateral acceleration; it feels as if the pilot is being pushed out of the seat sideways. Another way is to examine the slip-skid indicator and keep the ball in the center. Pilots should develop a feel for the particular airplanes they fly and understand how to minimize sideslip angle through coordinated use of flight controls.

Crossover speed is a recently coined term that describes the lateral controllability of an airplane with the rudder at a fixed (up to maximum) deflection. It is the minimum speed (weight and configuration dependent) in a 1-g flight, where maximum aileron/spoiler input (against the stops) is reached and the wings are still level or at an angle to maintain directional control. Any additional rudder input or decrease in speed will result in an unstoppable roll into the direction of the deflected rudder or in an inability to maintain desired heading. Crossover speed is very similar in concept to Vmca, except that instead of being Vmc due to a thrust asymmetry, it is Vmc due to full rudder input. This crossover speed is weight and configuration dependent. However, it is also sensitive to angle of attack. With weight and configuration held constant, the crossover speed will increase with increased angle of attack and will decrease with decreased angle of attack. Thus, in an airplane upset due to rudder deflection with large and increasing bank angle and the nose rapidly falling below the horizon, the input of additional nose-up elevator with already maximum input of aileron/spoilers will only aggravate the situation. The correct action in this case is to unload the airplane to reduce the angle of attack, which will regain aileron/spoiler effectiveness and allow recovery. This action may not be intuitive and will result in a loss of altitude.

Note: The previous discussion refers to the aerodynamic effects associated with rudder input; however, similar aerodynamic effects are associated with other surfaces.

2.5.5.5 High-Speed, High-Altitude Characteristics

Modern commercial jet transport airplanes are designed to fly at altitudes from sea level to more than 40,000 ft. There are considerable changes in atmospheric characteristics that take place over that altitude range, and the airplane must accommodate those changes.

One item of interest to pilots is the air temperature as altitude changes. Up to the tropopause (36,089 ft in a standard atmosphere), the standard temperature decreases with altitude. Above the tropopause, the standard temperature remains relatively constant. This is important to pilots because the speed of sound in air is a function only of air temperature. Aerodynamic characteristics of lifting surfaces and entire airplanes are significantly affected by the ratio of the airspeed to the speed of sound. That ratio is Mach number. At high altitudes, large Mach numbers exist at relatively low calibrated airspeeds.

As Mach number increases, airflow over parts of the airplane begins to exceed the speed of sound. Shock waves associated with this local supersonic flow can interfere with the normally smooth flow over the lifting surfaces, causing local flow separation. Depending on the airplane, as this separation grows in magnitude with increasing Mach number, characteristics such as pitchup, pitchdown, or aerodynamic buffeting may occur. Transport category airplanes are certificated to be free from characteristics that would interfere with normal piloting in the normal flight envelope and to be safely controllable during inadvertent exceedances of the normal envelope, as discussed in Section 2.5.4, "Aerodynamic Flight Envelope."

The point at which buffeting would be expected to occur is documented in the Approved Flight Manual. The Buffet Boundary or Cruise Maneuver

8

All transport airplanes demonstrate positive stability in at least some sense. The importance here is that the concept of stability can apply to a number of different parameters, all at the same time. Speed stability, the condition of an airplane returning to its initial trim airspeed after a disturbance, is familiar to most pilots. The same concept applies to Mach number. This stability can be independent of airspeed if, for example, the airplane crosses a cold front. When the outside air temperature changes, the Mach number changes, even though the indicated airspeed may not change. Airplanes that are "Mach stable" will tend to return to the original Mach number. Many jet transport airplanes incorporate Mach trim to provide this function. Similarly, commercial airplanes are stable with respect to load factor. When a gust or other disturbance generates a load factor, the airplane is certificated to be stable: it will return to its initial trimmed load factor (usually 1.0). This "maneuvering stability" requires a sustained pull force to remain at elevated load factors—as in a steep turn.

One important side effect of stability is that it allows for some unattended operation. If the pilot releases the controls for a short period of time, stability will help keep the airplane at the condition at which it was left.

Another important side effect of stability is that of tactile feedback to the pilot. On airplanes with static longitudinal stability, for example, if the pilot is holding a sustained pull force, the speed is probably slower than the last trim speed.

2.5.5.7 Maneuvering in Pitch

Movement about the lateral axis is called "pitch," as depicted in Figure 30.

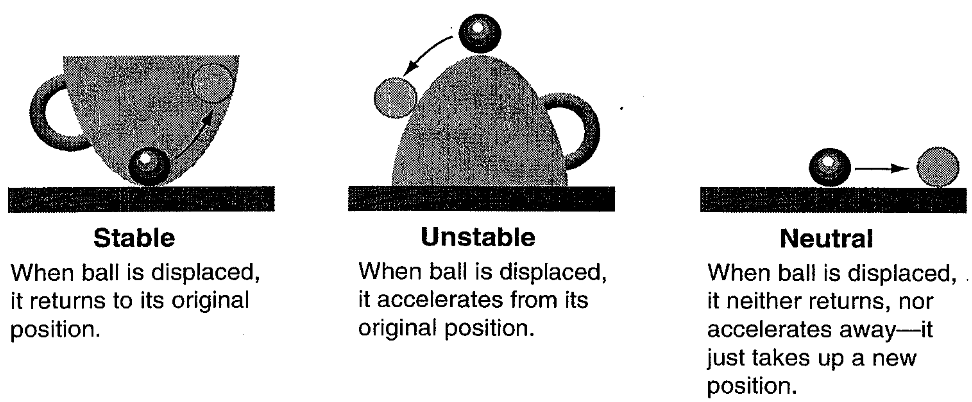


Figure 29
Static Stability

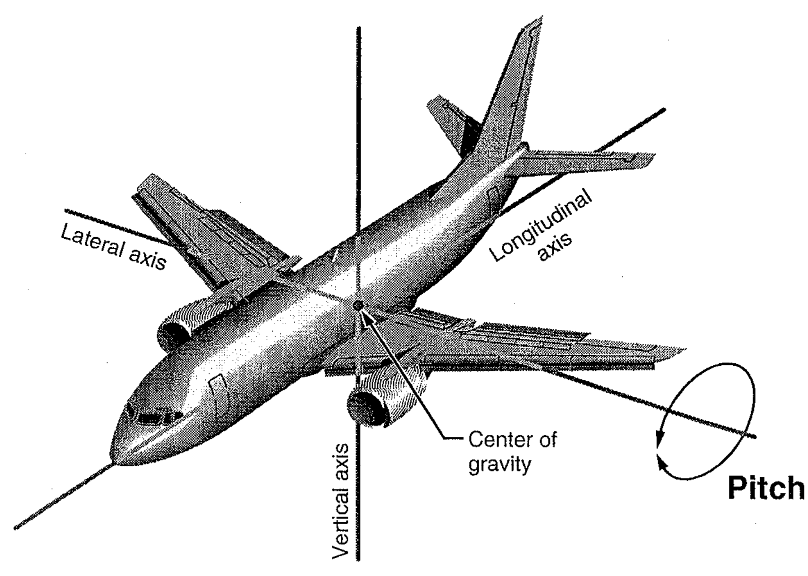


Figure 30
Reference Axis Definitions

9

the speed and sinkrate, the pilot pulls on the column and applies up-elevator. However, at a large bank angle, the only effect of the up-elevator is to further tighten the turn. It is imperative to get the wings close to level before beginning any aggressive pitching maneuver. This orients the lift vector away from the gravity vector so that the forces acting on the airplane can be managed in a controlled way.

Knowledge of these relationships is useful in other situations as well. In the event that the load factor is increasing, excess lift is being generated, and the pilot does not want speed to decrease, bank angle can help to keep the flight path vector below the horizon, getting gravity to help prevent loss of airspeed. In this situation, the excess lift can be oriented toward the horizon and, in fact, modulated up and down to maintain airspeed.

2.5.5.9 Lateral Maneuvering

Motion about the longitudinal axis (Fig. 35) is called "roll." Modern jet transport airplanes use combinations of aileron and spoiler deflections as primary surfaces to generate rolling motion. These deflections are controlled by the stick or wheel, and they are designed to provide precise maneuvering capability. On modern jet airplanes, the specific deflection combinations of ailerons and spoilers are usually designed to make adverse yaw virtually undetectable to the pilot. Even so, coordinated use of rudder in any lateral maneuvering should keep sideslip to a minimum.

As described in Section 2.5.5, "Aerodynamics," trailing edge control surfaces lose effectiveness in the downgoing direction at high angles of attack. Similarly, spoilers begin to lose effectiveness as the stall angle of attack is exceeded.

Transport airplanes are certificated to have positive unreversed lateral control up to a full aerodynamic stall. That is, during certification testing, the airplane has been shown to have the capability of producing and correcting roll up to the time the airplane is stalled. However, beyond the stall angle of attack, no generalizations can be made. ***For this reason it is critical to reduce the angle of attack at the first indication of stall so that control surface effectiveness is preserved.***

The apparent effectiveness of lateral control, that is, the time between the pilot input and when the airplane responds, is in part a function of the airplane's inertia about its longitudinal axis. Airplanes with very long wings, and, in particular, airplanes with engines distributed outboard along the wings, tend to have very much larger inertias than airplanes with engines located on the fuselage. This also applies to airplanes in which fuel is distributed along the wing span. Early in a flight with full wing (or tip) tanks, the moment of inertia about the longitudinal axis will be much larger than when those tanks are nearly empty. This greater inertia must be overcome by the rolling moment to produce a roll acceleration and resulting roll angle, and the effect is a "sluggish" initial response. As discussed before, airplanes of large mass and large inertia require that pilots be prepared for this longer response time and plan appropriately in maneuvering.

From a flight dynamics point of view, the greatest power of lateral control in maneuvering the airplane—in using available energy to maneuver the flight path—is to orient the lift vector. In particular, pilots need to be aware of their ability to orient the lift vector with respect to the gravity vector. Upright with wings level, the lift vector is opposed to the gravity vector, and vertical flight path is controlled by longitudinal control and thrust. Upright with wings not level, the lift vector is not aligned with gravity, and the flight path will be curved. In addition, if load factor is not increased beyond 1.0, that is, if lift on the wings is not greater than weight, the vertical flight path will become curved in the downward direction, and the airplane will begin to descend. Hypothetically, with the airplane inverted, lift and gravity point in the same direction: down. The vertical flight path will be-

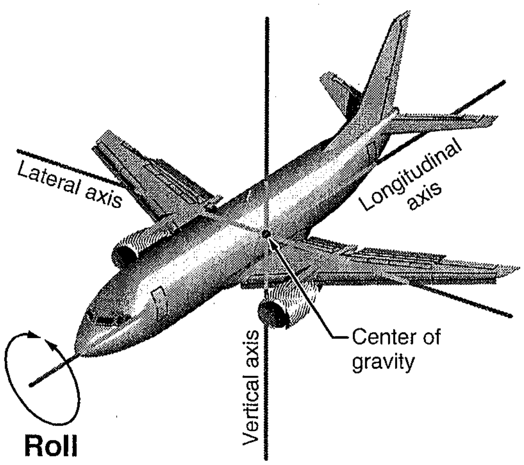


Figure 35
Roll Axis

10

second largest force acting on the airplane is the weight vector. Getting the airplane maneuvered so that the lift vector points in the desired direction should be the first priority, and it is the first step toward managing the energy available in the airplane.

2.6 Recovery From Airplane Upsets

Previous sections of this training aid review the causes of airplane upsets to emphasize the principle of avoiding airplane upsets. Basic aerodynamic information indicates how and why large, swept-wing airplanes fly. That information provides the foundation of knowledge necessary for recovering an airplane that has been upset. This section highlights several issues associated with airplane upset recovery and presents basic recommended airplane-recovery techniques for pilots. There are infinite potential situations that pilots can experience while flying an airplane. The techniques that are presented in this section are applicable for most situations.

2.6.1 Situation Awareness of an Airplane Upset

It is important that the first actions for recovering from an airplane upset be correct and timely. Guard against letting the recovery from one upset lead to a different upset situation. ***Troubleshooting the cause of the upset is secondary to initiating the recovery. Regaining and then maintaining control of the airplane is paramount.***

It is necessary to use the primary flight instruments and airplane performance instruments when analyzing the upset situation. While visual meteorological conditions may allow the use of references outside the airplane, it normally is difficult or impossible to see the horizon. This is because in most large commercial airplanes the field of view is restricted. For example, the field of view from an airplane that exceeds 25-deg, nose-up attitude probably is limited to a view of the sky. Conversely, the field of view is restricted to the ground for a nose-down pitch attitude that exceeds 10 deg. In addition, pilots must be prepared to analyze the situation during darkness and when instrument meteorological conditions (IMC) exist. Therefore, the Attitude Direction Indicator (ADI) is used as a primary reference for recovery. Compare the ADI information with performance instrument indications before initiating recovery. For a nose-low upset, normally the airspeed is increasing, altitude is decreasing, and the VSI indicates a descent. For a nose-high upset, the airspeed normally is decreasing, altitude is increasing, and the VSI indicates a climb. Cross-check other attitude sources, for example, the Standby Attitude Indicator and the Pilot Not Flying (PNF) instruments.

Pitch attitude is determined from the ADI Pitch Reference Scales (sometimes referred to as Pitch Ladder Bars). Most modern airplanes also use colors (blue for sky, brown for ground) or ground perspective lines to assist in determining whether the airplane pitch is above or below the horizon. Even in extreme attitudes, some portion of the sky or ground indications is usually present to assist the pilot in analyzing the situation.

The Bank Indicator on the ADI should be used to determine the airplane bank.

Situation analysis process:

- Locate the Bank Indicator.
- Determine pitch attitude.
- Confirm attitude by reference to other indicators.
- Assess the energy.

Recovery techniques presented later in this section include the phrase, ***"Recognize and confirm the situation."*** This situation analysis process is used to accomplish that technique.

2.6.2 Miscellaneous Issues Associated With Upset Recovery

Several issues associated with recovering from an upset have been identified by pilots who have experienced an airplane upset. In addition, observation of pilots in a simulator training environment has also revealed useful information associated with recovery.

2.6.2.1 Startle Factor

It has already been stated that airplane upsets do not occur very often and that there are multiple causes for these unpredictable events. Therefore, pilots are usually surprised or startled when an upset occurs. There can be a tendency for pilots to react before analyzing what is happening or to fixate on one indication and fail to properly diagnose the situation. Proper and sufficient training is the best solution for overcoming the startle factor.

11

The pilot must overcome the surprise and quickly shift into analysis of what the airplane is doing and then implement the proper recovery. ***Gain control of the airplane and then determine and eliminate the cause of the upset.***

2.6.2.2 Negative G Force

Airline pilots are normally uncomfortable with aggressively unloading the g forces on a large passenger airplane. They habitually work hard at being very smooth with the controls and keeping a positive 1-g force to ensure flight attendant and passenger comfort and safety. Therefore, they must overcome this inhibition when faced with having to quickly and sometimes aggressively unload the airplane to less than 1 g by pushing down elevator.

Note: It should not normally be necessary to obtain less than 0 g.

While flight simulators can replicate normal flight profiles, most simulators cannot replicate sustained negative-g forces. Pilots must anticipate a significantly different cockpit environment during less-than-1-g situations. They may be floating up against the seat belts and shoulder harnesses. It may be difficult to reach or use rudder pedals if they are not properly adjusted. Unsecured items such as flight kits, approach plates, or lunch trays may be flying around the cockpit. These are things that the pilot must be prepared for when recovering from an upset that involves forces less than 1-g flight.

2.6.2.3 Use of Full Control Inputs

Flight control forces become less effective when the airplane is at or near its critical angle of attack or stall. Therefore, pilots must be prepared to use full control authority, when necessary. The tendency is for pilots not to use full control authority because they rarely are required to do this. This habit must be overcome when recovering from severe upsets.

2.6.2.4 Counter-Intuitive Factors

Pilots are routinely trained to recover from *approach* to stalls. The recovery usually requires an increase in thrust and a relatively small reduction in pitch attitude. Therefore, it may be counter-intuitive to use greater unloading control forces or to reduce thrust when recovering from a high angle of attack, especially at lower altitudes. If the airplane is stalled while already in a nose-down attitude, the pilot must still push the nose down in order to reduce the angle of attack. Altitude cannot be maintained and should be of secondary importance.

2.6.2.5 Previous Training in Nonsimilar Airplanes

Aerodynamic principles do not change, but airplane design creates different flight characteristics. Therefore, training and experience gained in one model or type of airplane may or may not be transferable to another. For example, the handling characteristics of a fighter-type airplane cannot be assumed to be similar to those of a large, commercial, swept-wing airplane.

2.6.2.6 Potential Effects on Engines

Some extreme airplane upset situation may affect engine performance. Large angles of attack can reduce the flow of air into the engine and result in engine surges or compressor stalls. Additionally, large and rapid changes in sideslip angles can create excessive internal engine side loads, which may damage an engine.

2.6.3 Airplane Upset Recovery Techniques

An Airplane Upset Recovery Team comprising representatives from airlines, pilot associations, airplane manufacturers, and government aviation and regulatory agencies developed the techniques presented in this training aid. These techniques are not necessarily procedural. Use of both primary and secondary flight controls to effect the recovery from an upset are discussed. Individual operators must address procedural application within their own airplane fleet structure. The Airplane Upset Recovery Team strongly recommends that procedures for initial recovery emphasize the use of primary flight controls (aileron, elevator, and rudder). However, the application of secondary flight controls (stabilizer trim, thrust vector effects, and speedbrakes) may be considered incrementally to supplement primary flight control inputs after the recovery has been initiated.

12

For instructional purposes, several different airplane upset situations are discussed. These include the following:

- Nose high, wings level.
- Nose low, wings level.
  - Low airspeed.
  - High airspeed.
- High bank angles.
  - Nose high.
  - Nose low.

This provides the basis for relating the aerodynamic information and techniques to specific situations. ***At the conclusion of this recovery techniques section, recommended recovery techniques are summarized into two basic airplane upset situations: nose-high and nose-low.*** Consolidation of recovery techniques into these two situations is done for simplification and ease of retention.

◆ Following several situations, where appropriate, abbreviated techniques used for recovery are indicated by the solid diamond shown here.

Airplanes that are designed with electronic flight control systems, commonly referred to as "fly-by-wire" airplanes, have features that should minimize the possibility that the airplane would enter into an upset and assist the pilot in recovery, if it becomes necessary. But, when fly-by-wire airplanes are in the degraded flight control mode, the recovery techniques and aerodynamic principles discussed in this training aid are appropriate. Some environmental conditions can upset any airplane. But the basic principles of recognition and recovery techniques still apply, independent of flight control architecture.

Airplane autopilots and autothrottles are intended to be used when the airplane is within its normal flight regime. ***When an airplane has been upset, the autopilot and autothrottle must be disconnected as a prelude to initiating recovery techniques.*** Assessment of the energy is also required.

2.6.3.1 Stall

The recovery techniques assume the airplane is not stalled. An airplane is stalled when the angle of attack is beyond the stalling angle. A stall is characterized by any of, or a combination of, the following:

a. Buffeting, which could be heavy at times.
b. A lack of pitch authority.
c. A lack of roll control.
d. Inability to arrest descent rate.

These characteristics are usually accompanied by a continuous stall warning.

A stall must not be confused with stall warning that occurs before the stall and warns of an approaching stall. Recovery from an approach to stall warning is not the same as recovering from a stall. An approach to stall is a controlled flight maneuver. A stall is an out-of-control condition, but it is recoverable. ***To recover from the stall, angle of attack must be reduced below the stalling angle—apply nose-down pitch control and maintain it until stall recovery.*** Under certain conditions, on airplanes with underwing-mounted engines it may be necessary to reduce thrust to prevent the angle of attack from continuing to increase. ***If the airplane is stalled, it is necessary to first recover from the stalled condition before initiating upset recovery techniques.***

2.6.3.2 Nose-High, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 25 deg, nose high, and increasing.

Airspeed decreasing rapidly.

Ability to maneuver decreasing.

Start by disengaging the autopilot and autothrottle and recognize and confirm the situation. Next, apply nose-down elevator to achieve a nose-down pitch rate. This may require as much as full nose-down input. If a sustained column force is required to obtain the desired response, consider trimming off some of the control force. However, it may be difficult to know how much trim should be used; therefore, care must be taken to avoid using too much trim. Do not fly the airplane using pitch trim, and stop trimming nose-down as the required elevator force lessens. If at this point the pitch rate is not immediately under control, there are several additional techniques that may be tried. The use of these techniques depends on the circumstances of the situation and the airplane control characteristics.

Pitch may be controlled by rolling the airplane to a bank angle that starts the nose down. The angle of bank should not normally exceed approximately 60 deg. Continuous nose-down elevator pressure

13

will keep the wing angle of attack as low as possible, which will make the normal roll controls effective. With airspeed as low as the onset of the stick shaker, or lower, up to full deflection of the ailerons and spoilers can be used. The rolling maneuver changes the pitch rate into a turning maneuver, allowing the pitch to decrease. (Refer to Fig. 33.) In most situations, these techniques should be enough to recover the airplane from the nose-high, wings-level upset. However, other techniques may also be used to achieve a nose-down pitch rate.

If altitude permits, flight tests have shown that an effective method for getting a nose-down pitch rate is to reduce the power on underwing-mounted engines. (Refer to Sec. 2.5.5.11, "Flight at Extremely Low Airspeeds.") This reduces the upward pitch moment. In fact, in some situations for some airplane models, it may be necessary to reduce thrust to prevent the angle of attack from continuing to increase. This usually results in the nose lowering at higher speeds, and a milder pitchdown. This makes it easier to recover to level flight.

If control provided by the ailerons and spoilers is ineffective, rudder input may be required to induce a rolling maneuver for recovery. ***Only a small amount of rudder input is needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control.*** Caution must be used when applying rudder because of the low-energy situation. (Refer to Sec. 2.5.5.10, "Directional Maneuvering.")

To complete the recovery, roll to wings level, if necessary, as the nose approaches the horizon. Recover to slightly nose-low attitude to reduce the potential for entering another upset. Check airspeed, and adjust thrust and pitch as necessary.

Nose-high, wings-level recovery:

- ◆ Recognize and confirm the situation.
- ◆ Disengage autopilot and autothrottle.
- ◆ Apply as much as full nose-down elevator.
- ◆ Use appropriate techniques:
  - Roll to obtain a nose-down pitch rate.
  - Reduce thrust (underwing-mounted engines).
- ◆ Complete the recovery:
  - Approaching horizon, roll to wings level.
  - Check airspeed, adjust thrust.
  - Establish pitch attitude.

2.6.3.3 Nose-Low, Wings-Level Recovery Techniques

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

Airspeed low.

Recognize and confirm the situation. Disengage the autopilot and autothrottle. Even in a nose-low, low-speed situation, the airplane may be stalled at a relatively low pitch. It is necessary to recover from the stall first. This may require nose-down elevator, which may not be intuitive. Once recovered from the stall, apply thrust. The nose must be returned to the desired pitch by applying nose-up elevator. Avoid a secondary stall, as indicated by stall warning or airplane buffet. Airplane limitations of g forces and airspeed must be respected. (Refer to Sec. 2.5.2, "Energy States.")

Situation: Pitch attitude unintentionally more than 10 deg, nose low.

Airspeed high.

Recognize and confirm the situation. Disengage the autopilot and autothrottle. Apply nose-up elevator. Then it may be necessary to cautiously apply stabilizer trim to assist in obtaining the desired nose-up pitch rate. Stabilizer trim may be necessary for extreme out-of-trim conditions. Reduce thrust, and, if required, extend speedbrakes. The recovery is completed by establishing a pitch, thrust, and airplane configuration that corresponds to the desired airspeed. (Refer to Sec. 2.5.2, "Energy States.") Remember that a very clean airplane can quickly exceed its limits. When applying nose-up elevator, there are several factors that the pilot should consider. Obviously, it is necessary to avoid impact with the terrain. Do not enter into an accelerated stall by exceeding the stall angle of attack. Airplane limitations of g forces and airspeed should also be respected.

Nose-low, wings-level recovery:

- ◆ Recognize and confirm the situation.
- ◆ Disengage autopilot and autothrottle.
- ◆ Recover from stall, if necessary.
- ◆ Recover to level flight:
  - Apply nose-up elevator.
  - Apply stabilizer trim, if necessary.
  - Adjust thrust and drag, as necessary.

14

2.6.3.4 High-Bank-Angle Recovery Techniques

Bank angles can exceed 90 deg. In high-bank situations, the primary objective is to roll the airplane in the shortest direction to near wings level. However, if the airplane is stalled, it is first necessary to recover from the stall.

Situation: Bank angle greater than 45 deg.

Pitch attitude greater than 25 deg, nose high.

Airspeed decreasing.

A nose-high, high-angle-of-bank attitude requires deliberate flight control inputs. A large bank angle is helpful in reducing excessively high pitch attitudes. (Refer to Sec. 2.5.5.8, "Mechanics of Turning Flight.") Recognize and confirm the situation. Disengage the autopilot and autothrottle. Unload (reduce the angle of attack) and adjust the bank angle, not to exceed 60 deg, to achieve a nose-down pitch rate. Maintain awareness of energy management and airplane roll rate. To complete the recovery, roll to wings level as the nose approaches the horizon. Recover to a slightly nose-low attitude. Check airspeed and adjust thrust and pitch as necessary.

Situation: Bank angle greater than 45 deg.

Pitch attitude lower than 10 deg, nose low.

Airspeed increasing.

A nose-low, high-angle-of-bank attitude requires prompt action, because altitude is rapidly being exchanged for airspeed. Even if the airplane is at an altitude where ground impact is not an immediate concern, airspeed can rapidly increase beyond airplane design limits. Recognize and confirm the situation. Disengage the autopilot and autothrottle. Simultaneous application of roll and adjustment of thrust may be necessary. ***It may be necessary to unload the airplane by decreasing backpressure to improve roll effectiveness. If the airplane has exceeded 90 deg of bank, it may feel like "pushing" in order to unload. It is necessary to unload to improve roll control and to prevent pointing the lift vector towards the ground.*** Full aileron and spoiler input may be necessary to smoothly establish a recovery roll rate toward the nearest horizon. It is important that positive g force not be increased or that nose-up elevator or stabilizer trim be used until the airplane approaches wings level. If the application of full lateral control (ailerons and spoilers) is not satisfactory, it may be necessary to apply rudder in the direction of the desired roll. As the wings approach level, extend speedbrakes, if required. Complete the recovery by establishing a pitch, thrust, and airplane drag device configuration that corresponds to the desired airspeed. In large transport-category airplanes, do not attempt to roll through (add pro-roll controls) during an upset in order to achieve wings level more quickly. Roll in the shortest direction to wings level.

2.6.3.5 Consolidated Summary of Airplane Recovery Techniques

These summaries incorporate high-bank-angle techniques.

NOSE-HIGH RECOVERY:

- ◆ Recognize and confirm the situation.
- ◆ Disengage autopilot and autothrottle.
- ◆ Apply as much as full nose-down elevator.
- ◆ Use appropriate techniques:
  - Roll (adjust bank angle) to obtain a nose-down pitch rate.
  - Reduce thrust (underwing-mounted engines).
- ◆ Complete the recovery:
  - Approaching the horizon, roll to wings level.
  - Check airspeed, adjust thrust.
  - Establish pitch attitude.

NOSE-LOW RECOVERY:

- ◆ Recognize and confirm the situation.
- ◆ Disengage autopilot and autothrottle.
- ◆ Recover from stall, if necessary.
- ◆ Roll in the shortest direction to wings level—bank angle more than 90 deg: unload and roll.
- ◆ Recover to level flight:
  - Apply nose-up elevator.
  - Apply stabilizer trim, if necessary.
  - Adjust thrust and drag as necessary.

15

Example Airplane Upset Recovery Training Program

3.0 Introduction

The overall goal of the *Airplane Upset Recovery Training Aid* is to increase the ability of pilots to *recognize and avoid* situations that may lead to airplane upsets and improve the pilots' ability to recover control of an airplane that has exceeded the normal flight regime. This may be accomplished by increasing awareness of potential upset situations and knowledge of aerodynamics and by application of this knowledge during simulator training scenarios. Therefore, an academic and training program is provided to support this goal.

This "Example Airplane Upset Recovery Training Program" is structured to stand alone, but it may be integrated into existing initial, transition, and recurrent training and check programs, if desired. The Academic Training Program is designed to improve awareness by increasing the pilot's ability to recognize and avoid those situations that cause airplanes to become upset. The academic program also provides aerodynamic information associated with large, jet, swept-wing airplanes. This information provides the basis for understanding aircraft behavior in order to avoid upsets and for understanding why various upset recovery techniques are recommended. Finally, airplane upset recovery techniques are provided for pilots to use to return an airplane to the normal flight regime once it has been upset.

The Simulator Training Program includes a simulator briefing outline and simulator exercises. These exercises are designed for pilots to analyze upset situations and properly apply recovery techniques. A methodical building block approach is used so that pilots can learn the effect of each recovery technique and develop the required piloting skills in applying them. The recommended exercises are the minimum that pilots should accomplish. Operators are encouraged to develop additional exercises and scenarios. Recurrent training should, to the maximum extent possible, use real-time situation-integrated presentations with various levels of automation. Over several recurrent cycles, flight crews should be presented with upsets involving various levels of pilot and automation interface. Good communication, crew coordination, and other skills associated with crew resource management should be an integral part of recurrent training in upset recovery. Use of airplane systems, flight control, or engine malfunctions to accomplish these objectives is encouraged. However, training scenarios should not exceed the limitations of simulator engineering data or mechanical operation. Use of simulators beyond their mechanical or engineering data capabilities can lead to counterproductive learning and should be avoided. Operators are encouraged to assess the capabilities of their simulators and improve them, if necessary, to conduct this training. Simulator engineering information is provided in Appendix 3-D. The purpose of this information is to aid operators in assessing simulators.

3.1 Academic Training Program

The Academic Training Program focuses on the elements that are important to preventing an airplane from being upset and recovery techniques available for returning an airplane to the normal flight regime.

3.1.1 Training Objectives

The objectives of the training program are to provide the pilot with the following:

- Aerodynamic principles of large, swept-wing airplanes.
- The ability to recognize situations that may lead to airplane upsets so that they may be prevented.
- Airplane flight maneuvering information and techniques for recovering from an airplane upset.
- Skill in using upset recovery techniques.

A suggested syllabus is provided, with the knowledge that no single training format or curriculum is best for all operators or training situations. All training materials have been designed to "stand alone." As a result, some redundancy of the subject material occurs. However, using these materials together in the suggested sequence will enhance overall training effectiveness.

16

3.1.2 Academic Training Program Modules

The following academic training modules are available for preparing an academic training curriculum.

Pilot Guide. The "Pilot Guide to Airplane Upset Recovery" (*Airplane Upset Recovery Training Aid,* Sec. 2) is a comprehensive treatment of prevention and lessons learned from past upset accidents and incidents. The pilot guide is designed as a document that should be reviewed by an individual pilot at any time before formal upset recovery academic or simulator training.

Pilot Guide Questions. A set of questions based on the material contained in the Pilot Guide is contained in Appendix 3-A. These questions are designed to test the pilot's knowledge of each section of the Pilot Guide. In an airplane upset recovery curriculum, these questions may be used in one of two ways:

1. As part of a pilot's review of the Pilot Guide.
2. As an evaluation to determine the effectiveness of the pilot's self-study prior to subsequent academic or simulator training for upset recovery.

Airplane Upset Recovery Briefing. A paper copy of viewfoils with descriptive words for each one that can be used for a classroom presentation is contained in Appendix 3-B. The briefing supports a classroom discussion of the Pilot Guide.

Video (optional). *Airplane Upset Recovery*—This video is in two parts. Part One is a review of causes of the majority of airplane upsets. It emphasizes awareness as a means of avoiding these events. Part One also presents basic aerodynamic information about large, swept-wing airplanes. This part of the video provides the background necessary for understanding the principles associated with recovery techniques. Part Two presents airplane upset recovery techniques for several different upset situations. Part Two is excellent as an academic portion of recurrent training.

3.1.3 Academic Training Syllabus

Combining all of the previous academic training modules into a comprehensive training syllabus results in the following suggested Academic Training Program:

Training Module	Method of Presentation
Pilot Guide	Self-study/classroom
Pilot Guide Questions	Self-study/classroom
Video (optional)	Classroom
Airplane Upset Briefing	Classroom

3.1.4 Additional Academic Training Resources

The *Airplane Upset Recovery Training Aid* is provided in CD-ROM DOS format. The complete document and the two-part video are included in this format. This allows for more flexible training options and makes the information readily available to pilots. For example, the Pilot Guide (Sec. 2 of the document) may be printed from the CD-ROM format and distributed to all pilots.

3.2 Simulator Training Program

The Simulator Training Program addresses techniques that pilots should use to recover an airplane that has been upset. Training and practice are provided to allow the pilot to, as a minimum, recover from nose-high and nose-low airplane upsets. The exercises have been designed to meet the following criteria:

- Extensive simulator engineering modification will not be necessary.
- All exercises will keep the simulator within the mathematical models and data provided by the airplane manufacturer.
- Exercises will not result in negative or counter-productive training.

17

To be most effective, simulator training requires the pilot-in-training to be familiar with the material in the Academic Training Program.

Simulator training exercises are developed so that an operator needs only minimum training capability to encourage the implementation of an effective airplane upset recovery training program. The training exercises may be initiated by several means:

- Manual maneuvering to the demonstration parameters.
- Automated simulator presets.
- Stabilizer trim to induce the demonstration as best suits the pilot-in-training requirements.
- Other appropriate airplane-system, flight-control, or engine malfunctions.

Instructors may be called on to maneuver the simulator to assist the pilot-in-training in order to obtain the desired parameters and learning objectives. The instructors need to be properly trained to avoid nonstandardized or ineffective training.

3.2.1 Simulator Limitations

Simulator fidelity relies on mathematical models and data provided by the airplane manufacturer. The simulator is updated and validated by the manufacturer using flight data acquired during the flight test program. Before a simulator is approved for crew training, it must be evaluated and qualified by a regulatory authority. This process includes a quantitative comparison to actual flight data for certain test conditions, such as those specified in the International Civil Aviation Organization (ICAO) *Manual of Criteria for the Qualification of Flight Simulators*. These flight conditions represent airplane operation within the normal operating envelope.

When properly accomplished, the training recommended in this training aid should be within the normal operating envelope for most simulators. However, operators must assess their simulators to ensure their ability to support the exercises. This assessment should include, at a minimum, aerodynamic math models, their associated data tables, and the performance capabilities of visual, flight instrument and motion systems to support maneuvers performed in the simulator.

Appendix 3-D, "Flight Simulator Information," was developed to aid operators and training organizations in assessing their simulators. The information is provided by airplane manufacturers and based on the availability of information. Simulator manufacturers are another source for information.

The simulation may be extended to represent regions outside the typical operating envelope by using reliable predictive methods. However, flight data are not typically available for conditions where flight testing would be very hazardous. From an aerodynamic standpoint, the regimes of flight that are not generally validated fully with flight test data are the stall region and the region of high angle of attack with high-sideslip angle. While numerous approaches to stall or stalls are flown on each model (available test data are normally matched on the simulator) the flight controls are not fully exercised during an approach to stall, or during a full stall, because of safety concerns. Training maneuvers in this regime of flight must be carefully tailored to ensure that the combination of angle of attack and sideslip angle reached in the maneuver do not exceed the range of validated data or analytical/extrapolated data supported by the airplane manufacturer. The values of pitch, roll, and heading angles, however, do not affect the aerodynamics of the simulator or the validity of the training as long as angle of attack and sideslip angles do not exceed values supported by the airplane manufacturer. For example, a full 360-deg roll maneuver conducted without exceeding the valid range of the angle of attack and sideslip angle will be correctly replicated from an aerodynamic standpoint. However, the forces imposed on the pilot and the ratio of control forces to inertial and gravity forces will not be representative of the airplane.

18

Simulator technology continues to improve, which allows more training opportunities. However, trainers and pilots must understand that simulators still cannot replicate all things. For example, sustained g forces, both negative and positive, are not replicated. This means that a pilot cannot rely on complete sensory feedback that would be available in an actual airplane. Additionally, such things as loose items that would likely be floating in the cockpit during a negative-g situation are clearly not replicated in the simulator. However, a properly programmed simulator should provide accurate control force feedback (absent any sustained g loading), and the motion system should provide airframe buffet consistent with the aerodynamic characteristics of the airplane which could result from control input during certain recovery situations.

The importance of providing feedback to a pilot when control inputs would have exceeded airframe, physiological, or simulator model limits must be recognized and addressed. Some simulator operators have effectively used a simulator's "crash" mode to indicate limits have been exceeded. Others have chosen to turn the visual system red when given parameters have been exceeded. Simulator operators should work closely with training departments in selecting the most productive feedback method when selected parameters are exceeded.

3.2.2 Training Objectives

The objective of the Simulator Training Program is to provide pilots with the necessary experience and skills to

- Recognize and confirm airplane upset.
- Gain confidence and understanding in maneuvering the airplane during upsets.
- Successfully apply proper airplane upset recovery techniques.

3.2.3 Simulator Training Syllabus

The training given during initial, transition, and recurrent phases of training should follow a building block approach. The first time an upset is introduced, it should be well briefed and the pilot should have general knowledge of how the airplane will react. Since full limits of control forces may be necessary during a recovery from an upset, it may be appropriate to allow the pilot opportunity for maneuvering using all flight control inputs.

Exercises are initiated by the instructor pilot. Once the desired upset situation is achieved, the pilot-in-training then applies appropriate techniques to return the airplane to its normal flight regime or to maneuver the airplane during certain demonstrations, depending on the exercise. It may take several iterations before the pilot-in-training has the required skills for recovering the airplane.

3.2.4 Pilot Simulator Briefing

Pilots should be familiar with the material in the Ground Training Program before beginning Airplane Upset Recovery Training. However, a briefing should be given to review the following:

- Situation analysis process:
  - Callout of the situation.
  - Location of the Bank Indicator.
  - Determination of the pitch attitude.
  - Confirmation of attitude by reference to other indicators.
  - Assessment of the energy.
- Controlling the airplane before determining the cause of the upset.
- Use of full control inputs.
- Counter-intuitive factors.
- G-force factors.
- Use of automation.
- Recovery techniques for nose-high and nose-low upsets.

19

Exercise 1. Nose-High Characteristics (Initial Training)

Objective
Develop skills for recovery from a nose-high airplane upset.

General Description
This exercise should be used for initial training. The pilot is exposed to airplane nose-high aerodynamic characteristics. The exercise is designed to allow the pilot-in-training to develop proficiency in techniques for recovering from a nose-high airplane upset. Specifically, the pilot-in-training is required to recover from a minimum of a 40-deg, nose-high upset by recognizing and confirming the situation, verifying that the autopilot and autothrottle are disengaged, and applying appropriate recovery techniques. The first iteration requires the pilot-in-training to use up to full nose-down elevator. The second iteration requires the pilot-in-training to roll the airplane as a technique for reducing the pitch. The third iteration requires the pilot-in-training to use thrust reduction as a pitch-reduction recovery technique, if the airplane model has underwing-mounted engines. All iterations require the pilot to complete the recovery by rolling to wings level, if necessary, and, at the appropriate time, checking airspeed and establishing a final recovery pitch attitude.

Initial Conditions

Altitude:	1000 to 5000 ft above ground level.
Center of gravity:	Midrange.
Airspeed:	Maneuvering plus 50 kn.
Autopilot:	Disengaged.
Autothrottle:	Disengaged.
Attitude:	40-deg, nose-up pitch, wings level.

Exercise 1. Iteration One—Use of Nose-Down Elevator

Instructions for the Instructor Pilot

1. Establish initial conditions. Briefly point out or discuss the pitch-angle scale for various pitch attitudes. Have the pilot-in-training note the pitch attitude for the initial conditions.

2. Initiate the exercise by the following means:
   - Manual maneuvering to the demonstration parameters.
   - Automated simulator presets.
   - Stabilizer trim to induce the demonstration as best suits the pilot-in-training requirements.
   - Other appropriate airplane-system, flight-control, or engine malfunctions.

3. Transfer airplane control to the pilot-in-training.

4. Instruct the pilot-in-training to slowly release the control column and simultaneously increase thrust to maximum. As the airplane pitch attitude passes approximately 40 deg, instruct the pilot-in-training to initiate recovery by simulating disengaging the autopilot and autothrottle and countering pitch; by use of nose-down elevator; and, if required, by using stabilizer trim to relieve elevator control pressure.

5. The pilot-in-training completes the recovery when approaching the horizon by checking airspeed, adjusting thrust, and establishing the appropriate pitch attitude and stabilizer trim setting for level flight.

Common Instructor Pilot Errors

- Achieves inadequate airspeed at entry.
- Attains stall angle of attack because of too-aggressive pull-up.
- Does not achieve full parameters before transfer of airplane control to the pilot-in-training.

Common Pilot-in-Training Errors

- Fails to simulate disengaging the autopilot and autothrottle.
- Hesitates to use up to full control input.
- Overtrims nose-down stabilizer.

Exercise 1. Iteration Two—Use of Bank Angle

Instructions for the Instructor Pilot

1. Establish initial conditions.

2. Initiates the exercise by the following means:
   - Manual maneuvering to the demonstration parameters.
   - Automated simulator presets.
   - Stabilizer trim to induce the demonstration as best suits the pilot-in-training requirements.
   - Other appropriate airplane-system, flight-control, or engine malfunctions.

3. Slowly release the control column and simultaneously increase thrust to maximum.

4. Transfer airplane control to the pilot-in-training.

5. Allow the simulator to pitch up until approximately 40 deg.

6. Have the pilot-in-training roll the airplane until a nose-down pitch rate is detected.

7. The pilot-in-training completes the recovery when approaching the horizon by rolling to wings level and slightly nose low, checking airspeed, adjusting thrust, and establishing the appropriate pitch attitude and stabilizer trim setting for level flight.

Common Pilot-in-Training Errors

- Achieves the required roll too slowly, which allows the nose to drop too slowly and airspeed to become excessively low.
- Continues the roll past what is required to achieve a nose-down pitch rate; therefore, the difficulty of recovery is unnecessarily increased.
- Rolls out at a pitch attitude that is too high for conditions and encounters an approach to stall.

21

Exercise 1. Iteration Three—Thrust Reduction (Underwing-Mounted Engines)

Instructions for the Instructor Pilot

1. Establish initial conditions.

2. Initiate the exercise by the following means:
   - Manual maneuvering to the demonstration parameters.
   - Automated simulator presets.
   - Stabilizer trim to induce the demonstration as best suits the pilot-in-training requirements.
   - Other appropriate airplane-system, flight-control, or engine malfunctions.

3. Slowly release the control column and simultaneously increase thrust to maximum.

4. Allow the airplane to pitch up until 40 deg.

5. Transfer airplane control to the pilot-in-training.

6. Instruct the pilot-in-training to initiate recovery by reducing thrust to approximately midrange until a detectable nose-down pitch rate is achieved.

7. The pilot-in-training completes the recovery when approaching the horizon by checking airspeed, adjusting thrust, and establishing the appropriate pitch attitude and stabilizer trim setting for level flight.

Common Pilot-in-Training Errors

- Fails to simulate disengaging the autopilot and autothrottle.
- Fails to reduce thrust sufficiently to obtain nose-down pitch.
- Reduces thrust excessively.

22

Exercise 2. Nose-Low Characteristics (Initial Training)

Objectives
- Demonstrate low-speed and high-speed accelerated stalls.
- Develop skills for recovery from a nose-low airplane upset.

General Description

This exercise should be used for initial training. Selected iterations should also be used for recurrent training as determined by the operator. The pilot is exposed to airplane nose-low aerodynamic characteristics. The exercise is designed to demonstrate what an approach to accelerated stall is and how to recover from it. The pilot-in-training is required to recover from a minimum of a 20-deg, nose-low upset. High-bank-angle (up to inverted flight), nose-low upset iterations are used. To recover, the pilot-in-training recognizes and confirms the situation and verifies that the autopilot and autothrottle are disengaged. Thrust is adjusted for the appropriate energy condition. For a satisfactory nose-low recovery, the pilot-in-training must avoid ground impact and accelerated stall and respect g-force and airspeed limitations. The pilot-in-training is required to recover to stabilized flight with a pitch, thrust, and airplane configuration that corresponds to the desired airspeed.

Initial Conditions

Altitude:	1000 to 10,000 ft above ground level.
Center of gravity:	Midrange.
Airspeed:	L/D maximum or minimum maneuvering.
Autopilot:	Disengaged.
Autothrottle:	Disengaged.
Attitude:	Level flight, then establish up to 20 deg, nose low, and about 60 deg, of bank.

Exercise 2. Iteration One—High Entry Airspeed

Instructions for the Instructor Pilot

1. Begin the exercise while in level flight.
2. Have the pilot-in-training roll the airplane to 60 deg with no attempt to maintain altitude.
3. Have the pilot-in-training observe the nose drop and airspeed increase and the outside view of the ground.
4. Instruct the pilot-in-training to recover by recognizing and confirming the situation; verifying that the autopilot and autothrottle are disengaged; rolling to approaching wings level, then applying nose-up elevator; applying stabilizer trim, if necessary; and adjusting thrust and drag as necessary.

23

Common Pilot-in-Training Errors

- Forgets to disengage the autopilot and or autothrottle.
- Fails to use full control inputs.
- Initiates pull-up before approaching wings level.
- Attempts to precisely obtain wings level and delays pull-up.
- Enters secondary stall.
- Exceeds positive g force during pull-up.
- Fails to reduce thrust to idle for high speed.
- Fails to use speedbrakes, if required.
- Achieves inadequate pull-up to avoid ground impact.

Exercise 2. Iteration Two—Accelerated Stall Demonstration

Instructions for the Instructor Pilot

1. Establish initial conditions.

2. Initiate the exercise by the following means:
   - Manual maneuvering to the demonstration parameters.
   - Automated simulator presets.
   - Stabilizer trim to induce the demonstration as best suits the pilot-in-training requirements.
   - Other appropriate airplane-system, flight-control, or engine malfunctions.

Note: For manual maneuvering to the demonstration parameters, the instructor pilot applies nose-up elevator assisted with a small amount of nose-up stabilizer trim to slowly achieve up to 20-deg, nose-high pitch. Do not change the entry thrust. Allow the airspeed to decrease. Upon reaching approximately 20 deg of nose-up pitch, the instructor pilot rolls the airplane until a nose-down pitch rate is achieved. The instructor pilot holds that bank angle until the nose is well below the horizon.

3. Have the pilot-in-training note the reduced ability to visually detect the horizon once below 10 deg, nose low.

4. Transfer airplane control to the pilot-in-training.

5. When approximately 20 deg below the horizon, instruct the pilot-in-training to slowly apply backpressure while maintaining the bank angle. Sufficient backpressure is applied until achieving stick shaker. Note the airspeed, and unload to eliminate stick shaker. Again, after allowing bank to increase and pitch to go lower, have the pilot-in-training slowly apply backpressure until achieving stick shaker. Note the airspeed, and unload and initiate recovery.

6. Recovery is accomplished by recognizing and confirming the situation and verifying that the autopilot and autothrottle are disengaged. The pilot-in-training rolls to approaching wings level and then recovers to level flight by applying nose-up elevator and nose-up stabilizer trim, if necessary, and adjusting thrust and drag as necessary.

Common Instructor Pilot Errors

- Allows airspeed to become excessive for final recovery.
- Allows the pilot-in-training to pull to stick shaker too quickly, and angle of attack exceeds simulator fidelity.
- Allows the pilot-in-training to reduce bank angle and pitch before final recovery.

24

Exercise 2. Iteration Three—High Bank Angle/Inverted Flight

Instructions for the Instructor Pilot

1. Establish initial conditions.

2. Initiate the exercise by the following means:
   - Manual maneuvering to the demonstration parameters.
   - Automated simulator presets.
   - Stabilizer trim to induce the demonstration as best suits the pilot-in-training requirements.
   - Other appropriate airplane-system, flight-control, or engine malfunctions.

Note: For manual maneuvering to the demonstration parameters, the instructor pilot applies nose-up elevator assisted with small amounts of nose-up stabilizer trim to slowly achieve up to 20 deg of pitch. Do not change the entry thrust.

3. Transfer airplane control to the pilot-in-training.

4. At approximately 20 deg of nose-up pitch, the pilot-in-training rolls the airplane until a nose-down pitch rate is achieved. Use a roll rate that will achieve 120 deg of bank at about 20 deg, nose low.

5. Have the pilot-in-training note the reduced ability to visually detect the horizon.

6. When approximately 20 deg below the horizon, the pilot-in-training recovers by recognizing and confirming the situation and verifying that the autopilot and autothrottle are disengaged. The pilot-in-training must unload and roll. The pilot-in-training, when approaching wings level, recovers to level flight by applying nose-up elevator and nose-up stabilizer trim, if necessary, and adjusting thrust and drag as necessary.

Common Instructor Pilot Errors
- Allows airspeed to become excessive for final recovery.
- Allows the pilot-in-training to pull to stick shaker too quickly and exceed stall angle of attack or g-force limit.
- Fails to notice improper control inputs.

Common Pilot-in-Training Errors
- Forgets to disengage the autopilot or autothrottle.
- Fails to unload.
- Fails to use sufficient control inputs.
- Initiates pull-up before approaching wings level.
- Attempts to precisely obtain wings level and delays pull-up.
- Exceeds positive g-force limits during pull-up.
- Fails to reduce thrust to idle for high speed.
- Fails to use speedbrakes, if required.
- Achieves inadequate pull-up to avoid ground impact.

25

Exercise 3. Optional Practice Exercise

Objectives

- Develop skills for recovery from a nose-high, low-energy airplane upset.
- Expose the pilot to a realistic airplane upset that requires disengaging the autopilot and autothrottle.

General Description

This exercise may be used for initial training modified for the airplane model. It is a good example for a recurrent training scenario. The instructor pilot is not required to occupy a pilot position. No additional training time is required, since a normal takeoff and departure is continued. The pilots are exposed to a nose-high, low-energy situation. It allows the pilot-in-training to experience a challenging airplane upset recovery. The focus of this exercise is on the entry and recovery from an airplane upset, not on the engine thrust reduction. Malfunction analysis or nonnormal procedure accomplishment should not be done. A normal takeoff is made. During the second segment climb with the autopilot and autothrottle engaged at 1000 ft above ground level, thrust is reduced to idle on one engine (the outboard engine for airplanes with more than two engines). The intent is to create a nose-high, significant yaw and roll condition with decreasing airspeed. When the bank angle is approximately 45 deg, the instructor pilot informs the pilot-in-training to recover by using appropriate recovery techniques. After recovery, normal thrust is restored.

Initial Conditions

Altitude:	1000 ft above ground level and climbing.
Center of gravity:	Midrange.
Airspeed:	Second segment climb airspeed.
Autopilot:	Engaged.
Autothrottle:	Engaged.
Thrust:	As required.
Target parameters:	45-deg bank angle. Autopilot and autothrottle engaged. Minimum of 1000 ft above ground level.

Exercise 3. Instructions for the Simulator Instructor

1. Establish initial conditions.
2. Reduce thrust to idle on one engine (the outboard engine for airplanes with more than two engines). Maintain thrust on other engine(s).
3. Have the pilot-in-training observe the developing yaw and roll condition and decreasing airspeed.
4. Upon passing 45 deg of bank, instruct the pilot-in-training to recover by assessing the energy, disengaging the autopilot and autothrottle, and applying appropriate recovery techniques. Roll control may require as much as full aileron and spoiler input and use of coordinated rudder.
5. After recovery, normal thrust is used and training continues.

26

Common Instructor Pilot Errors

- Autopilot and autothrottle are not engaged at 1000 ft above ground level.
- Has the pilot-in-training initiate recovery before allowing the autopilot to fly to 45 deg of bank angle.

Common Pilot-in-Training Errors

- Forgets to disengage the autopilot or autothrottle.
- Fails to unload.
- Fails to use full control inputs.
- Fails to complete the recovery before ground impact.

27

Recurrent Training Exercises

The pilot-in-training should be given the opportunity to review the airplane handling characteristics. Those events identified as pre-exercise practice are appropriate for this review. The length of review should depend on pilot-in-training experience and skill level.

Recurrent training should incorporate a nose-high situation. This situation can be induced by the pilot-in-training, or by the Pilot Not Flying (PNF) (with perhaps the pilot-in-training closing his or her eyes to force an assessment of the situation and energy), or by conditions available to the instructor by the use of simulator engineering. The pilot-in-training should recover by using appropriate techniques discussed in initial training.

Recurrent training should incorporate a nose-low, high-bank-angle situation. This situation can be induced by the pilot-in-training, or by the PNF (with perhaps the pilot-in-training closing his or her eyes to force an assessment of the situation and energy), or by conditions available to the instructor by the use of simulator engineering. The pilot-in-training should recover by using appropriate techniques discussed in initial training.

28

Flight Simulator Information

General Information

The ability of the simulators in existence today to adequately replicate the maneuvers being proposed for airplane upset recovery training is an important consideration. Concerns raised about simulators during the creation of the *Airplane Upset Recovery Training Aid* include the adequacy of the hardware, the equations of motion, and the aerodynamic modeling to provide realistic cues to the flight crew during training at unusual attitudes.

It is possible that some simulators in existence today may have flight instruments, visual systems or other hardware that will not replicate the full six-degree-of-freedom movement of the airplane that may be required during unusual attitude training. It is important that the capabilities of each simulator be evaluated before attempting airplane upset training and that simulator hardware and software be confirmed as compatible with the training proposed.

Properly implemented equations of motion in modern simulators are generally valid through the full six-degree-of-freedom range of pitch, roll, and yaw angles. However, it is possible that some existing simulators may have equations of motion that have unacceptable singularities at 90, 180, 270, or 360 deg of roll or pitch angle. Each simulator to be used for airplane upset training must be confirmed to use equations of motion and math models (and associated data tables) that are valid for the full range of maneuvers required. This confirmation may require coordination with the airplane and simulator manufacturer.

Operators must also understand that simulators cannot fully replicate all flight characteristics. For example, motion systems cannot replicate sustained linear and rotational accelerations. This is true of pitch, roll, and yaw accelerations, and longitudinal and side accelerations, as well as normal load factor, "g's." This means that a pilot cannot rely on all sensory feedback that would be available in an actual airplane. However, a properly programmed simulator should provide accurate control force feedback and the motion system should provide airframe buffet consistent with the aerodynamic characteristics of the airplane which could result from control input during certain recovery situations.

The importance of providing feedback to a pilot when control inputs would have exceeded airframe, physiological, or simulator model limits must be recognized and addressed. Some simulator operators have effectively used a simulator's "crash" mode to indicate limits have been exceeded. Others have chosen to turn the visual system red when given parameters have been exceeded. Simulator operators should work closely with training departments in selecting the most productive feedback method when selected parameters are exceeded.

The simulation typically is updated and validated by the airplane manufacturer using flight data acquired during the flight test program. Before a simulator is approved for any crew training, it must be evaluated and qualified by a national regulatory authority. This process includes a quantitative comparison of simulation results to actual flight data for certain test conditions such as those specified in the ICAO *Manual of Criteria for the Qualification of Flight Simulators*. These flight conditions represent airplane operation within the normal operating envelope.

The simulation may be extended to represent regions outside the typical operating envelope using wind tunnel data or other predictive methods. However, flight data are not typically available for conditions where flight testing would be very hazardous. From an aerodynamic standpoint, the regimes of flight that are usually not fully validated with flight data are the stall region and the region of high angle of attack with high sideslip angle where there may be separated airflow over the wing or empennage surfaces. While numerous approaches to stall or stalls are flown on each model (available test data are normally matched on the simulator), the flight controls are not fully exercised during an approach to stall or during a full stall, because of safety concerns. Also, roll and yaw rates and sideslip angle are carefully controlled during stall maneuvers to be near zero; therefore, validation of derivatives involving these terms in the stall region is not possible. Training maneuvers in this regime of flight must be carefully tailored to ensure that the combination of angle of attack and sideslip angle reached during the maneuver does not exceed the range of validated data or analytical/extrapolated data supported by the airplane manufacturer.

Values of pitch, roll, and heading angles, however, do not directly affect the aerodynamic characteristics of the airplane or the validity of simulator training as long as angle of attack and sideslip angles do not exceed values supported by the airplane manufacturer. For example, the aerodynamic characteristics of the upset experienced during a 360-deg roll maneuver will be correctly replicated if the maneuver is conducted without exceeding the valid range of angle of attack and sideslip.

Simulator Alpha-Beta Data Plots

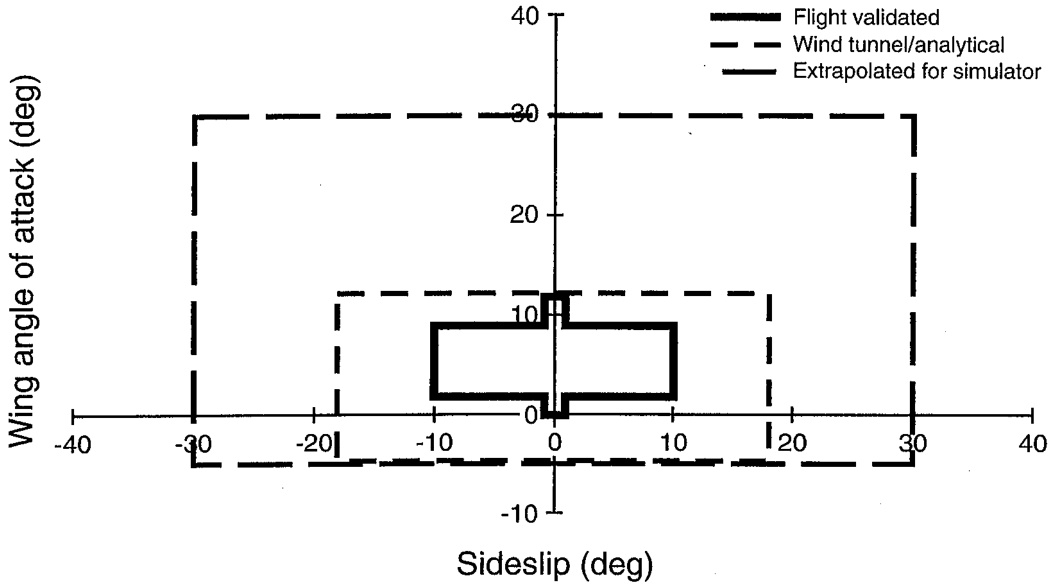
The aerodynamic model for each simulation may be divided into regions of various "confidence levels," depending on the degree of flight validation or source of predictive methods if supported by the airplane manufacturer, correctly implemented by the simulator manufacturer and accurately supported and maintained on an individual simulator. These confidence levels may be classified into three general areas:

1. High: Validated by flight test data for a variety of tests and flight conditions.
2. Medium: Based on reliable predictive methods.
3. Low: Extrapolated.

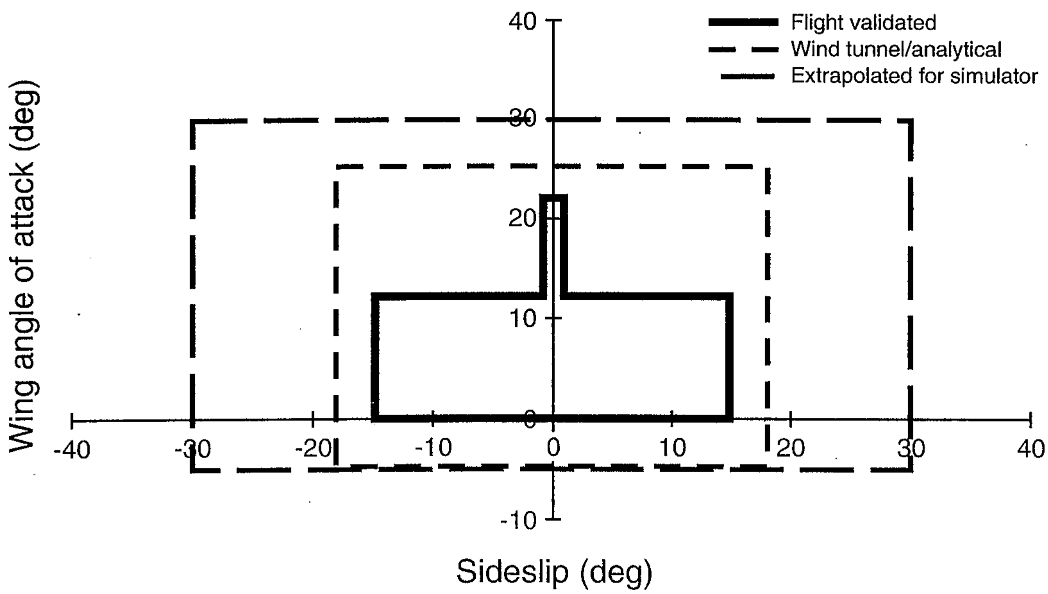
The flaps up data represent the maximums achieved at low speeds flaps up and do not imply that these values have been achieved at or near cruise speeds. For flaps down, the maximums were generally achieved at landing flaps, but are considered valid for the flaps down speed envelope.

30

A300/A310 Flaps Up Alpha/Beta Envelope



A300/A310 Alpha/Beta Envelope



31