

#### A/NZSASI June 2007

## Threat and Error Management (TEM) and High Altitude Operations

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- Statistics History
- > The 1998 Upset Training Aid
- Highlights of the Changes
- > High Altitude Maneuvers
- > Upset Recovery Techniques







#### Airplane Accidents Worldwide Commercial Jet Fleet – 2005

Date	Airline	Airplane Type	Accident Location	Fatalities	Phase	Description
03-Jan-05	Asia Airlines	737-200	Banda Aceh, Indonesia		Landing	Airplane struck water buffalo
08-Jan-05	Aero Republica	MD-80	Cali, Colombia		Landing	Landing overrun
12-Jan-05	Myanmar Airways	F-28	Myeik, Myanmar (Burma)		Landing	Nose landing gear collapse
18-Jan-05	Novair	A321	Sharm El-Sheikh, Egypt		Landing	Tailstrike
23-Jan-05	Spanair	MD-80	Asturias, Spain		Landing	Hard landing
24-Jan-05	Atlas Air	747-200F	Dusseldorf, Germany		Landing	Landing overrun in snowstorm
25-Jan-05	Republic of Yugoslavia	F-100	Podgorica, Yugoslavia		Landing	Veered off icy runway
01-Feb-05	Air France	A319	Paris, France	1	Parked	Cabin attendant fell
02-Feb-05	El Al Israel Airlines	747-200	Tel Aviv, Israel		Takeoff	Thrown tire tread after takeoff
03-Feb-05	Kam Air	737-200	Kabul, Afghanistan	104	Approach	Crashed into mountain
25-Feb-05	Syrianair	727-200	Kuwait City, Kuwait		Landing	Runway excursion
02-Mar-05	Continental Airlines	777-200	Newark, New Jersey, USA		Takeoff	Tailstrike
06-Mar-05	Delta Air Lines	757-200	Boston, Massachusetts, USA		Taxi	Flight attendant injured during taxi
07-Mar-05	Iraq Ministry of Defense	A310	Tehran, Iran		Landing	Veered off runway
19-Mar-05	Ethiopian Airlines	707-300F	Entebbe, Uganda		Landing	Landed short, crashed into lake
01-Apr-05	El Al Israel Airlines	737-800	Tel Aviv, Israel		Parked	Cabin attendant fell
07-Apr-05	ICARO	F-28	Coca, Ecuador		Landing	Hard landing short MLG collapse
14-Apr-05	Merpati Nusantara Airlines	737-200	Ujung, Pandang, Indonesia		Landing	Veered off runway
20-Apr-05	Iranian Air Force	707-300F	Tehran, Iran	3	Landing	Landing overrun into river
05-May-05	Northwest Airlines	DC-9	Minneapolis, Minnesota, USA		Parked	Airplane hit by fuel truck while parked
10-May-05	Northwest Airlines	DC-9	Minneapolis, Minnesota, USA		Taxi	Airplane collision during taxi
10-May-05	Northwest Airlines	A319	Minneapolis, Minnesota, USA		Parked	Struck by taxiing airplane
13-May-05	Delta Air Lines	MD-80	Denver, Colorado, USA		Climb	Air turn back - loss of pressurization
13-May-05	Lufthansa Cargo	747-200	Shariah, United Arab Emirates		Landing	LH main gear partially retracted
22-May-05	Skyservice Airlines	767-300ER	Punta Cana, Dominican Republic		Landing	Hard derotation - skin wrinkling
26-May-05	Alitalia	MD-80	Prague, Czech Republic		Pushback	Failure of nose landing gear
31-May-05	Adam Air	737-400	Jakarta Soekarno, Indonesia		Landing	Right main landing gear collapsed
07-Jun-05	UPS	MD-11	Louisville, Kentucky, USA		Landing	Nose wheel separated
12-Jun-05	Chanchangi Airlines	727-200	Lagos Nigeria		Landing	Off-runway excursion
19-Jun-05	Mahfooz Aviation	707-300	Addis Ababa, Ethiopia		Landing	Hard landing - MLG collapse
01-Jul-05	Biman Bangladesh Airlines	DC-10	Chittagong, Bangladesh		Landing	Veered off runway - MLG collapse
02-Aug-05	Air France	A340	Toronto, Canada		Landing	Runway overrun and burned
09-Aug-05	Saudia	MD-90	Cairo Egypt		Landing	Engine fire on landing
14-Aug-05	Helios Airways	737-300	Grammatikos Greece	121	Climb	Elight crew incapacitation
16-Aug-05	West Caribbean Airways	MD-82	Machigues, Venezuela	160	Cruise	Loss of control
19-Aug-05	Northwest Airlines	747-200	Agana Guam		Landing	Landed with nose landing gear retracted
23-Aug-05	Tans	737-200	Pucalloa Peru	45	Landing	Crashed while attempting to land
24-Aug-05	SAS	A340	Shanghai China		Takeoff	Tailstrike on takeoff
05-Sep-05	Mandala Airlines	737-200	Medan, Indonesia	145	Takeoff	Crashed during takeoff
08-Sep-05	Saudia	747-300	Colombo, Sri Lanka		Taxi	Evacuation fatality and injuries
18-Sep-05	Spirit Airlines	A321	Et Lauderdale Florida USA		Landing	Tailstrike
09-Oct-05	Sahara India Airlines	737-400	Mumbai India		Landing	Runway overrun
22-Oct-05	Bellview Airlines	737-200	Lagos Nigeria	117	Climb	Crashed during climb
31-Oct-05	MIBA Aviation	727-100	Kindu D R Congo		Landing	Landing overrun
14-Nov-05	Asian Spirit	BAe 146	Catarman Philippines		Landing	Runway overrun
08-Dec-05	Southwest Airlines	737-700	Chicago Illinois USA		Landing	Runway overrun
10-Dec-05	Sosoliso Airlines	DC-9	Port Harcourt Nigeria	107	Approach	Crashed during go-around
14-Dec-05	FedEx	727-200	Memphis Tennessee LISA		Pushback	Airplane collision with tow tractor
23-Dec-05	Koda Air	707-300	Istanbul Turkey		Parked	Airplane fire on ground
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2005 STATISTICAL SUMMARY, MAY 2006



Date	Operator	Aircraft	Location	Phase	Fatal		
Jan. 8, 2005	AeroRepública	MD-80	Cali, Colombia	Landing	0		
Jan. 24, 2005	Atlas Air	747-200	Dusseldorf, Germany	Landing	0		
Feb. 3, 2005	Air West Cargo	II-76	Khartoum, Sudan	Approach	7		
Feb. 3, 2005	Kam Air	737-200	Kabul, Afghanistan	Approach	104	G	
March 19, 2005	Race Cargo Airline	707-300	Entebbe, Uganda	Approach	0	C	Every one of those
March 23, 2005	Airline Transport	II-76	Mwanza, Tanzania	Takeoff	8	0	15 CEIT assidanta i
April 7, 2005	ICARO Air	F-28	Coca, Ecuador	Landing	0		15 CFIT accidents
April 20, 2005	Saha Air	707-300	Tehran, Iran	Landing	З		2005 — and indee
lune 19, 2005	Mahfooz Aviation	707	Addis Ababa, Ethiopia	Landing	0		
luly 1, 2005	Biman Bangladesh	DC-10	Chittagong, Bangladesh	Landing	0		every CFIT accider
Aug. 2, 2005	Air France	A340	Toronto, Canada	Landing	0		in history-
Aug. 14, 2005	Helios Airways	737-300	Grammatikos, Greece	Enroute	121		
							happened to aircra
Aug. 23, 2005	TANS Peru Airlines	737-200	Pucallpa, Peru	Approach	45	G	
Sept. 5, 2005	Mandala Airlines	737-200	Medan-Polonia, Indonesia	Takeoff	104	O	not equippe
Oct. 22, 2005	Bellview Airlines	737-200	Lissa, Nigeria	Climb	117		with TAW
Oct. 31, 2005	MIBA Aviation	727	Kindu, DR Congo	Landing	0		
Nov. 11, 2005	Royal Airlines Cargo	11-76	Khak-e Shahidan, Afghanistan	Approach	8	G	
Dec. 10, 2005	Sosoliso Airlines	DC-9	Port Harcourt, Nigeria	Approach	109	0	

Source: Boeing, Airclaims

# West Caribbean MD-82 Maracaibo, Venezuela 16 August 2005





# West Caribbean MD-82 16 August 2005

- Chartered flight from Panama City to Martinique, impact site in a rural area near the town of Machiques, Venezuela.
   152 pax (all French Citizens); 8 crew (Colombian) – all fatal
- Shortly before entering Venezuelan airspace, crew began to request lower altitudes (from FL330).
- Crew indicated to ATC that they had 'dual engine flameout'.
- Last contact from crew is at FL140 and descending; airplane not controllable.
- Recorders were read out by the BEA in France.
- French and Venezuelan authorities conducting separate investigations.

### **ISSUES:**

SPEED DECAY FOLLOWED BY AERODYNAMIC STALL AFTER LEVELING AT CRUISE ALTITUDE

RADAR DATA: VERY HIGH RATE OF DESCENT FROM FL 330 TO 14,300 - RADAR CONTACT LOST

CONVECTIVE ACTIVITY IN VICINITITY OF THE ACCIDENT







## Stick Shaker Events

Moderate turbulence - Encountered at FL390 (ON TOP OF CLOUDS VMC) associated with convective clouds (CB) around and heavy crosswind (60-90 knots). Weather radar was on and we noticed clouds below and radar returns indications of the presence of CB's. The cabin crew were seated and seatbelt sigh had been switched on. **IAS tape was fluctuating** speed cannot be reached) few times. At this point we hit severe turbulence in VMC and "stick shaker" had been activated for 1 second and aircraft banked to the left side. The autopilot and autothrottle were disengaged immediately and descent to FL370 initiated. Moderate turbulence continued for the next 10 minutes at FL370.

# Stick Shaker Events

60 MILES BEFORE A T/STORM REQUESTED 15 DEGS RIGHT FROM ATC TO AVOID TO **INCREASE SEPARATION TO APPROX 30 MILES. ATC GRANTED REQUEST. PASSED** ABEAM T/STORM ABOUT 30 MILES TO EAST AT FL380. TAILWIND DROPPED AND SPEED RAPIDLY WASHED OFF. MCT APPLIED INTIALLY. WING AND ENG ANTI-ICE IMMEDIATLY SWITCHED ON AS ICE SEEN RAPIDLY FORMING ON WIPERS AND WINDSCREEN. TOLD ATC WE HAD TO DESCEND AND COULD NOT MAINTAIN 380 AND THEY CLEARED US TO DESCEND FL240. WHILE LEAVING FL380 STALL WARNING MOMENTARILY WENT OFF AND AERODYNAMIC BUFFET FELT WITH ACOMMPANYING SEVERE TURBULANCE. STOPPED ALMOST IMMEDIATLY WITH FURTHER PITCH DOWN AND THRUST. NORMAL FLIGHT PARAMATERS REGAINED BEFORE FL360. LEVELLED OFF AT FL360 AND FLIGHT CONTINUED NORMALLY. PIREP MADE TO ATC OF SEVERE ICING IN THE AREA AT FL380. OTHER PARAMETERS NOTED IMMEDIATLY AFTER THE EVENT: SAT -56DEGS. FMC CRZ PAGE OPT/MAX 375/398. WIND 180/50 IMMEDIATLY BEFORE INCIDENT. NOTED AT 220/22 IMMEDIATLY AFTER EVENT.

## **Stick Shaker Event**



STICK SHAKER

A/P REMAINS

A/T DISCONNECTED

# HIGH ALTITUDE MANEUVERING

# PERFORMANCE

### **High Altitude Maneuvers**

**Discussion Topics** 

- Limits to Altitude Capability
- Maneuvering Issues Impact of thrust limits on turn margins
- Recommendations/Considerations for Operation at High Altitude

#### **Maximum Altitude**

There are three things that can limit Altitude Capability: Maximum Certified Altitude (Structural Limit) **Thrust-Limited Maximum Altitude** Defined by Thrust / Drag relationship User-defined Residual Rate of Climb (RROC) Temperature-dependent! **Buffet-Limited Maximum Altitude** Defined by Initial Buffet CL User-defined maneuver margin

#### **Maximum Altitude**

#### Enroute

#### Long Range Cruise Maximum Operating Altitude

These tables provide the maximum operating altitude in the same manner as the FMC. Maximum altitudes are shown for a given cruise weight and maneuver capability. Note that this table considers both thrust and buffet limits, providing the more limiting of the two. Any data that is thrust limited is denoted by an asterisk and represents only a thrust limited condition in level flight with 100 ft/min residual rate of climb. Flying above these altitudes with sustained banks in excess of approximately 15° may cause the airplane to lose speed and/or altitude. The altitudes shown in the table are limited to the maximum certified altitude of 41000 ft.

#### Flight Management System (FMS) Control Display Unit (CDU)

#### Airline Policy Page 1/2



### 737-800 Optimum and Maximum Altitudes





737-800 Optimum and Maximum Altitudes



-7 \*Denotes altitude thrust limited in level flight, 100 fpm residual rate of climb.

40500\*

-7

-7

-7

40500\*

40500\*

#### **Primary Flight Display (PFD) Airspeed** Indication

The amber band:

- displays the maneuver speed
- provides 1.3g/40
  degrees of bank
  angle (default)
  margin to buffet
- constant regardless
  of ambient
  temperature

NOTE: The amber band does not give any indication of thrust limits



The Boeing Company

Gross Weight = 70000 kg = 154323 lb Altitude = 35000 ft



Gross Weight = 70000 kg = 154323 lb

Altitude = 35000 ft



Gross Weight = 70000 kg = 154323 lb

Altitude = 35000 ft



Gross Weight = 70000 kg = 154323 lb

Altitude = 35000 ft



## 737-800 Maneuver Capability at Maximum Altitude

Standard Day



### 737-800 Maneuver Capability at Maximum Altitude

 $ISA + 20^{\circ}C Day$ 



#### **Recommendations/Considerations for Flight at High Altitudes**

#### To get accurate altitude limits from the FMC:

- Enter an accurate aircraft weight
- Enter an accurate temperature deviation at the cruising altitude

#### For LNAV operation:

- the FMC provides a real-time bank angle limiting function
- this function will protect the commanded bank angle from exceeding the current available thrust limit.
- this bank angle protection is not available when LNAV mode is deactivated.

### **Recommendations/Considerations for Flight at High Altitudes (cont)**

#### For LNAV deactivated:

- Fly at least 10 knots above the lower amber band
- If speed drops below the lower amber band limit, immediately increase speed by doing one or more of the following:
  - 1. Reduce bank angle (to 10 15° maximum)
  - 2. Increase thrust (up to maximum continuous thrust) as required
  - 3. Descend
- Limit bank angles to no more than 10° for manual steering in cruise (set MCP bank angle selector to 10° from TOC to TOD)



# Airplane Upset Recovery Training Aid Revision 1 Update



# 1998 Airplane Upset Recovery Training Aid

- > Industry Team Effort
  - Manufacturers
  - Airlines
  - Specialty Organizations





# 1998 Airplane Upset Recovery Training Aid





Aimed at Large Transport Category Airplanes



#### Loss of Control Accidents

A Historical Leader of Fatal Accidents



# Historically Divided Between Mechanical and Flight Crew Caused



# What the accident data shows us..

#### Variable Situations and Outcomes

#### Rare Events so Crews Became Startled






### What the accident data shows us..

Crews Sometimes Used Improper Inputs to Recover

Crews Training Generally Left Them Unprepared to Deal with Upsets and Recover







### What the accident data shows us...

Basic Flaws in Knowledge and Training Became Evident

Many Accidents were Recoverable with Proper Training





#### Early Efforts ---Upset Recovery Training

 Lack of Consensus on Content, Scope, Types of Training and Understanding

Need for Standardization





### **Reason for an Update**



 Continued Accidents and Incidents
 Some Important Upset Issues were Identified





### **Reason for an Update**

- Tragic Accident in New York
- Update Information in the Training Aid
- Need to get the Word Out!









**Pilot-Commanded Sideslip** 

> Roll due to sideslip



"Large aggressive control reversals can lead to loads that can exceed structural design limits"





#### **Pilot-Commanded Sideslip**

 Except crosswind takeoff and landings rudder, yaw damper, turn coordinators are to keep sideslip as close to zero as possible









Flight Control and Other Anomalies

Stall Warnings on Takeoff

- Incorrect V speed
- Incorrect Flap or Stabilizer Position
- Malfunctioning stall warning system
- Shift in CG during takeoff





### Revision 1 - Highlights Flight Control and Other Anomalies



# Adjust the Flight Profile Induced drag Shifts in CG







**Directional Maneuvering** 

- > Rudder Limiters
  - Limit authority
  - Two basic designs
  - Structural capability









Directional Maneuvering
"Dutch Roll"

- Overshoots of Sideslip
- Yaw Damper inoperative









#### **Simulator Training**

- > Limitations
  - Basic Fundamentals
  - Realities of simulation
  - Complexity







#### **Simulator Training**

- Fidelity Issues
  - Alpha and Beta Limits
  - Reactions and Responses









## UPSET RECOVERY VIDEO - PART 1 VIDEO - PART 2





# Upset Recovery

#### REVIEW

 Causes of Airplane Upsets
 Swept-wing Airplane Fundamentals

Airplane Upset Recovery Techniques



### What is "Airplane Upset?"



*Deing* 

Non-Normal Maneuvers Non-Normal Maneuver

737 Flight Crew Operations Manual

#### Upset Recovery

#### An

#### conditions:

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

The following techniques represent a logical progression for recovering the airplane. The sequence of actions is for guidance only and represents a series of options to be considered and used depending on the situation. Not all actions may be necessary once recovery is under way. If needed, use pitch trim sparingly. Careful use of rudder to aid roll control should be considered only if roll control is ineffective and the airplane is not stalled.

These techniques assume that the airplane is not stalled. A stalled condition can exist at any attitude and may be recognized by continuous stick shaker activation accompanied by one or more of the following:

- · Buffeting which could be heavy at times
- · Lack of pitch authority and/or roll control
- · Inability to arrest descent rate.

If the airplane is stalled, recovery from the stall must be accomplished first by applying and maintaining nose down elevator until stall recovery is complete and stick shaker activation ceases.

### **Causes of Airplane Upsets**

Environmentally induced

Systems anomalies induced

Pilot induced

> A combination of all three

### THREATS

#### **Environmental Causes**

- Turbulence
- Clear air turbulence
- Mountain wave
- Windshear
- Microbursts
- Wake turbulence
- Airplane Icing





### System Anomalies Induced

These causes primarily involve:

Flight Instruments

Autoflight systems

Flight controls and other anomalies





#### **Pilot Induced Causes of Upsets**

- Instrument misinterpretation or slow crosscheck
- Inattention and distraction from primary cockpit duties
- Vertigo or spatial disorientationImproper use of airplane automation



### STRATEGIES

#### **Review of Recovery Techniques**

■ Nose high, wings level ■ Nose low, wings level High bank angles ■ Nose high ■ Nose low Consolidated techniques for ■ Nose high ■ Nose low



RESIST

RESOLVE

### STRATEGIES

#### Upset Recovery

#### An

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exist at any attitude and may be recognized by continuous stick shaker activation accompanied by one or more of the following:

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- · Lack of pitch authority and/or roll control
- Inability to arrest descent rate.

#### **Startle Factor**



### **B717 – TEST FLIGHT**









#### NEW FRONTIERS AVIATION SAFETY





### **B717 – TEST FLIGHT**



#### **B717 – TEST FLIGHT**





TAT



BDEING

#### "Task Saturation"



#### Use of Full Control Inputs



#### **Non-intuitive Factors**



#### Stall Recovery





### Stall Recovery



## Recovery Techniques (cont)

Stall characteristics

■ Buffeting

Lack of pitch authority

Lack of roll control

Inability to arrest descent rate



### STRATEGIES

Non-Normal Maneuvers	Chapter NNM
Table of Contents	Section 0

Non-Normal Maneuvers	NNM.1.1
Approach to Stall Recovery	NNM.1.1
Rejected Takeoff	NNM.1.2
Terrain Avoidance < RYR >	NNM.1.3
Ground Proximity Caution	NNM.1.3
Ground Proximity Warning	NNM.1.3
Traffic Avoidance	NNM.1.5

	Nose High Recovery	NNM.1.8
	Nose Low Recovery	NNM.1.8
W	indshear	NNM.1.9
	Windshear Caution	NNM.1.9
	Windshear Warning	NNM.1.9
	Windshear Escape Maneuver	NNM.1.11

### Nose-High, Wings Level



Nose High Recovery			
### Nose-high, Wings Level Recovery Techniques

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

# Nose-Low, Wings Level



## STRATEGIES

#### PILOT FLYING

#### PILOT NOT FLYING

- Disconnect autopilot and autothrottle
- Recover from stall, if required
- \* Roll in shortest direction to wings level (unload and roll if bank angle is more than 90 degrees)

Recover to level flight:

- Apply nose up elevator
- \*Apply nose up trim, if required
- Adjust thrust and drag as required.

- Call out attitude, airspeed and altitude throughout the recovery
- Verify all required actions have been completed and call out any omissions.

WARNING: \* Excessive use of pitch trim or rudder may aggravate an upset situation or may result in loss of control and/or high structural loads.

# Nose-Low, Wings Level

 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

#### High Bank Angles

# Lift vectorLateral control



#### High Bank Angles

#### > Nose-high

Bank angle helps reduce high pitch attitudes

Must consider energy management

> Nose-low

Prompt action required Bank angle greater than 90 degrees considerations



## Conclusion

Know the causes of airplane upsets avoid them, when possible Be familiar with the flight dynamics and aerodynamics of your airplane Know the recovery techniques





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