Preface — Chapter PT
Chapter Table of Contents — Section 0

Preface . . . . . PT
Model Identification PT.1
Introduction PT.2
Abbreviations PT.3
Revision Record PT.4
List of Effective Pages - FAA Approved PT.5
General Information 1
Ground Operations 2
Takeoff and Initial Climb 3
Climb, Cruise, Descent and Holding 4
Approach and Missed Approach 5
Landing 6
Maneuvers 7
Non-Normal Operations 8
Maneuvers 9
Maneuvers 10
Index . . . . . Index

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DELTA

MD-88/90
Flight Crew Training Manual
FCTM
Delta Air Lines, Inc.

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Revision Number: 3
Revision Date: September 12, 2016

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General

The airplanes listed in the table below are covered in the operations manual. The table information is used to distinguish data peculiar to one or more, but not all of the airplanes. Where data applies to all airplanes listed, no reference is made to individual airplanes.

The procedures and information contained in this manual also apply to aircraft acquired by Delta Air Lines subsequent to the current revision; however, this document may not address all pertinent information for these airplanes. In such instances, specific operating procedures and systems information can be found in appropriate Differences Chapter(s) and/or Fleet Bulletin(s) prior to their incorporation in the next scheduled revision.

Ship number is supplied by the operator. Registry number is supplied by the national regulatory agency. Serial number is supplied by Boeing.

Ship Number	Registry Number	Serial Number	Model
0904	N904DL	49535	MD-88
0905	N905DL	49536	MD-88
0906	N906DL	49537	MD-88
0907	N907DL	49538	MD-88
0908	N908DL	49539	MD-88
0910	N910DL	49541	MD-88
0911	N911DL	49542	MD-88
0912	N912DL	49543	MD-88
0913	N913DL	49544	MD-88
0914	N914DL	49545	MD-88
0915	N915DL	49546	MD-88
0916	N916DL	49591	MD-88
0917	N917DL	49573	MD-88
0918	N918DL	49583	MD-88

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Ship Number	Registry Number	Serial Number	Model
0919	N919DL	49584	MD-88
0920	N920DL	49644	MD-88
0921	N921DL	49645	MD-88
0922	N922DL	49646	MD-88
0923	N923DL	49705	MD-88
0924	N924DL	49711	MD-88
0925	N925DL	49712	MD-88
0926	N926DL	49713	MD-88
0927	N927DA	49714	MD-88
0928	N928DL	49715	MD-88
0929	N929DL	49716	MD-88
0930	N930DL	49717	MD-88
0931	N931DL	49718	MD-88
0932	N932DL	49719	MD-88
0933	N933DL	49720	MD-88
0934	N934DL	49721	MD-88
0935	N935DL	49722	MD-88
0936	N936DL	49723	MD-88
0937	N937DL	49810	MD-88
0938	N938DL	49811	MD-88
0939	N939DL	49812	MD-88
0940	N940DL	49813	MD-88
0941	N941DL	49814	MD-88
0942	N942DL	49815	MD-88
0943	N943DL	49816	MD-88
0944	N944DL	49817	MD-88

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Ship Number	Registry Number	Serial Number	Model
0945	N945DL	49818	MD-88
0946	N946DL	49819	MD-88
0947	N947DL	49878	MD-88
0948	N948DL	49879	MD-88
0949	N949DL	49880	MD-88
0950	N950DL	49881	MD-88
0951	N951DL	49882	MD-88
0952	N952DL	49883	MD-88
0953	N953DL	49884	MD-88
0954	N954DL	49885	MD-88
0955	N955DL	49886	MD-88
0956	N956DL	49887	MD-88
0957	N957DL	49976	MD-88
0958	N958DL	49977	MD-88
0959	N959DL	49978	MD-88
0960	N960DL	49979	MD-88
0961	N961DL	49980	MD-88
0962	N962DL	49981	MD-88
0963	N963DL	49982	MD-88
0964	N964DL	49983	MD-88
0965	N965DL	49984	MD-88
0966	N966DL	53115	MD-88
0967	N967DL	53116	MD-88
0968	N968DL	53161	MD-88
0969	N969DL	53172	MD-88
0970	N970DL	53173	MD-88

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Ship Number	Registry Number	Serial Number	Model
0971	N971DL	53214	MD-88
0972	N972DL	53215	MD-88
0973	N973DL	53241	MD-88
0974	N974DL	53242	MD-88
0975	N975DL	53243	MD-88
0976	N976DL	53257	MD-88
0977	N977DL	53258	MD-88
0978	N978DL	53259	MD-88
0979	N979DL	53266	MD-88
0980	N980DL	53267	MD-88
0981	N981DL	53268	MD-88
0982	N982DL	53273	MD-88
0983	N983DL	53274	MD-88
0984	N984DL	53311	MD-88
0985	N985DL	53312	MD-88
0986	N986DL	53313	MD-88
0987	N987DL	53338	MD-88
0988	N988DL	53339	MD-88
0989	N989DL	53341	MD-88
0990	N990DL	53342	MD-88
0991	N991DL	53343	MD-88
0992	N992DL	53344	MD-88
0993	N993DL	53345	MD-88
0994	N994DL	53346	MD-88
0995	N995DL	53362	MD-88
0996	N996DL	53363	MD-88

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Ship Number	Registry Number	Serial Number	Model
0997	N997DL	53364	MD-88
0998	N998DL	53370	MD-88
0999	N999DN	53371	MD-88
9000	N900DE	53372	MD-88
9001	N901DE	53378	MD-88
9002	N902DE	53379	MD-88
9003	N903DE	53380	MD-88
9004	N904DE	53409	MD-88
9005	N905DE	53410	MD-88
9006	N906DE	53415	MD-88
9007	N907DE	53416	MD-88
9008	N908DE	53417	MD-88
9009	N909DE	53418	MD-88
9010	N910DE	53419	MD-88
9011	N911DE	49967	MD-88
9012	N912DE	49997	MD-88
9013	N913DE	49956	MD-88
9014	N914DE	49957	MD-88
9015	N915DE	53420	MD-88
9016	N916DE	53421	MD-88
9017	N917DE	49958	MD-88
9018	N918DE	49959	MD-88
9019	N919DE	53422	MD-88
9020	N920DE	53423	MD-88
9201	N901DA	53381	MD-90-30
9202	N902DA	53382	MD-90-30

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Ship Number	Registry Number	Serial Number	Model
9203	N903DA	53383	MD-90-30
9204	N904DA	53384	MD-90-30
9205	N905DA	53385	MD-90-30
9206	N906DA	53386	MD-90-30
9207	N907DA	53387	MD-90-30
9208	N908DA	53388	MD-90-30
9209	N909DA	53389	MD-90-30
9210	N910DN	53390	MD-90-30
9211	N911DA	53391	MD-90-30
9212	N912DN	53392	MD-90-30
9213	N913DN	53393	MD-90-30
9214	N914DN	53394	MD-90-30
9215	N915DN	53395	MD-90-30
9216	N916DN	53396	MD-90-30
9217	N917DN	53552	MD-90-30
9218	N918DH	53553	MD-90-30
9219	N919DN	53576	MD-90-30
9220	N920DN	53582	MD-90-30
9221	N921DN	53583	MD-90-30
9222	N922DX	53584	MD-90-30
9223	N923DN	53585	MD-90-30
9224	N924DN	53586	MD-90-30
9225	N925DN	53587	MD-90-30
9226	N926DH	53588	MD-90-30
9227	N927DN	53589	MD-90-30
9228	N928DN	53590	MD-90-30

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Ship Number	Registry Number	Serial Number	Model
9229	N929DN	53459	MD-90-30
9230	N930DN	53458	MD-90-30
9231	N931DN	53544	MD-90-30
9232	N932DN	53457	MD-90-30
9233	N933DN	53543	MD-90-30
9234	N934DN	53462	MD-90-30
9235	N935DN	53460	MD-90-30
9236	N936DN	53461	MD-90-30
9237	N937DN	53352	MD-90-30
9238	N938DN	53353	MD-90-30
9239	N939DN	53356	MD-90-30
9240	N940DN	53359	MD-90-30
9241	N941DN	53555	MD-90-30
9242	N942DN	53556	MD-90-30
9243	N943DN	53557	MD-90-30
9244	N944DN	53558	MD-90-30
9245	N945DN	53559	MD-90-30
9246	N946DN	53354	MD-90-30
9247	N947DN	53355	MD-90-30
9248	N948DN	53357	MD-90-30
9249	N949DN	53358	MD-90-30
9250	N950DN	53360	MD-90-30
9251	N951DN	53361	MD-90-30
9252	N952DN	53560	MD-90-30
9253	N953DN	53523	MD-90-30
9254	N954DN	53524	MD-90-30

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Ship Number	Registry Number	Serial Number	Model
9255	N955DN	53525	MD-90-30
9256	N956DN	53526	MD-90-30
9257	N957DN	53527	MD-90-30
9258	N958DN	53528	MD-90-30
9259	N959DN	53529	MD-90-30
9260	N960DN	53530	MD-90-30
9261	N961DN	53531	MD-90-30
9262	N962DN	53532	MD-90-30
9263	N963DN	53533	MD-90-30
9264	N964DN	60001	MD-90-30
9265	N965DN	60002	MD-90-30

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General

The Flight Crew Training Manual provides information and recommendations on maneuvers and techniques and is divided into ten chapters. General Information covers procedures and techniques not associated with a particular maneuver or phase of flight. Ground Operations covers information associated with aircraft preflight, engine starting and taxi operations including taxi operations in adverse weather conditions. Chapters 3 through 6 are titled by phase-of-flight and contain information about aircraft operations in each phase. The Maneuvers chapter covers maneuvers associated with climb, cruise, and descent, e.g., stall recovery and emergency descent. The Non-Normal Operations chapter covers non-normal situations that may occur during any phase of flight. The Human Factors chapter covers Crew Resource Management and Threat Management Tools. The Selected References chapter covers engine out, high elevation and performance considerations, turbulence and windshear avoidance, hydroplaning, and Delta maneuver training.

Flight crews are expected to perform the non-normal maneuvers, described in the FCTM, from memory.

Flight profiles show procedures for some all-engine and engine-inoperative situations.

Flight profiles do not include all procedural items but show required/recommended:

- configuration changes
- thrust changes
- Mode Control Panel (MCP) changes
- pitch mode and roll mode changes
- checklist completions.

Note: In the event of a conflict, the procedures and restrictions published in the Vol. 1, Vol. 2, QRH, MEL, Fleet Bulletin, or ODM take precedence over the information, techniques, and recommendations in the FCTM.

Note: Figures in this manual are to be used for training purposes only except where noted. This data is not suitable as a basis for performance calculations or other engineering purposes.

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Regulatory Agencies

Regulatory information in this manual is based upon FAA regulations and requirements unless otherwise indicated. Examples of regulations and requirements include, but are not limited to, FAR takeoff field requirements, aircraft approach categories, and low visibility approach criteria.

Airplane Configuration

The Flight Crew Training Manual (FCTM) is intended to provide information in support of procedures listed in the Operations Manual and techniques to help the pilot accomplish these procedures safely and efficiently. The FCTM is written in a format that is more general than the Operations Manual. It does not account for airplane configuration differences, unless these differences have an impact on the procedure or technique being discussed. For example, the FCTM states, "When the flaps are retracted and the airspeed approaches maneuvering speed, ensure CLB thrust is set." This statement is not intended to tell the crew how to set climb thrust, only to emphasize that the flight crew must ensure that CLB thrust is set. It is recognized that crew actions required to set climb thrust are different in different models. Reference to the applicable Operations Manual is required for information on how to set climb thrust.

In cases where a procedure or technique is applicable only to an airplane with a specific configuration, the annotation "as installed" is used. Airplane configuration differences are found in the Operations Manual. In the event of a conflict, the procedures published in the Operations Manual take precedence over information presented in the Flight Crew Training Manual.

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Corrections to the Manual

Log on to the Delta Flight Operations Portal, http://deltanet.delta.com and submit a Publications Change Request (PCR) to correct any errors or discrepancies discovered in this manual, or to submit a suggested change to any Aircraft Operating Manual, Volume 1, Volume 2, Quick Reference Handbook (QRH), Flight Crew Training Manual (FCTM), Normal Checklist, Airway Manual (AM), Flight Operations Manual (FOM), Operating Experience (OE/TOE) Guide, Fleet Bulletin (FB), or All Pilots Bulletin (APB).

There is a link to the PCR form at Deltanet > My Division > Administration > Forms and Reports. Once submitted, the PCR is automatically routed to the applicable Fleet Technical Manager and Technical Writer for that manual.

Organization

The operations manual is organized in the following manner.

Volume 1

- Preface - Contains general information regarding the manual's purpose, structure, and content. It also contains lists of abbreviations, a record of revisions and a list of effective pages.
- Limitations - Covers operational limitations.
- Normal Procedures - Covers all amplified normal operating procedures and are based on a thorough analysis of crew activity required to operate the aircraft, and reflect the latest knowledge and experience available.
- Normal Operational Information - Contains reference material used to support normal procedures.
- Supplementary Procedures is organized by system and covers:
  - any procedure that is non-routine in nature,
  - any first-flight-of-the-day test or other systems test,
  - guidance on lengthy operating procedures, and
  - adverse weather procedures and guidance.
- Differences - Notes differences between aircraft models and variants.

Volume 2

- Preface - Contains general information regarding the manual's purpose, structure, and content. It also contains lists of abbreviations, a record of revisions and a list of effective pages.
- Contains general aircraft and systems information. These chapters are generally subdivided into sections covering controls and indicators and systems descriptions.

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QRH

- Non-normal checklists - Contains checklists used to manage non-normal situations.
- Non-Normal Operational Information - Contains reference material used to support non-normal procedures.
- Non-Normal Checklist Instructions - Contains non-normal checklist instructions and evacuation flow/philosophy.
- Revision Record - Contains general information regarding the manual's purpose, structure, and content. It also contains lists of abbreviations, a record of revisions and a list of effective pages.

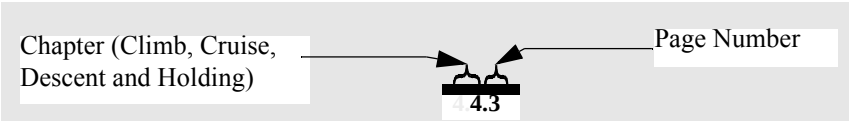
FCTM

- Preface - Contains general information regarding the manual's purpose, structure, and content. It also contains lists of abbreviations, a record of revisions and a list of effective pages.
- Provides information and recommendations on aircraft operations, maneuvers, and techniques, and human factors.

Page Numbering

The Flight Crew Training Manual uses a decimal page numbering system. While the other manuals use a three-field number system, the Flight Crew Training Manual page number is divided into two fields; chapter and page. An example of a page number for the Climb, Cruise, Descent and Holding chapter follows: chapter 4, page 3.

Example Page Number



Warnings, Cautions, and Notes

The following levels of written advisories are used throughout the manual.

Warning - A warning is an instruction about a hazard that if ignored could result in injury, loss of aircraft control, or loss of life. A warning will appear prior to the applicable step or item.

WARNING: Do not pressurize any hydraulic or pneumatic system until clearance is obtained from Maintenance.

Caution - A caution is an instruction concerning a hazard that if ignored could result in damage to equipment. A caution will appear prior to the applicable step or item.

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CAUTION: Do not set takeoff thrust until oil temperature is above 50°C.

Note - A note provides amplified information, instruction, or emphasis. A note will appear after the applicable step or item.

Note: The checklist must not be modified in any way.

Aircraft Effectivities

Differences in aircraft configuration are shown by use of aircraft effectivities throughout Volumes 1 and 2, QRH, and the FCTM. The following rules are used to express aircraft effectivities:

- Aircraft effectivities are listed by model and/or ship number. A range of aircraft is defined by a dash, e.g. 9901 - 9910. A comma in the effectivity range indicates a break in the range, e.g. 9901 - 9910, 9912 - 9925; aircraft 9911 is excluded from the range. Aircraft introduced to the fleet following manual publication are effective as subsequent ships, e.g. 9901 & Subsequent.
- Aircraft effectivities are listed in bold text throughout the manual, except in the Limitations chapter. In the Limitations chapter, aircraft effectivities are listed in bold when the effectivity applies to the entire section or subsection. When the effectivity applies only to a step within a section, it is listed in normal text.
- Aircraft effectivities apply only to the paragraph, illustration, operational note, procedural step, etc. and to subordinate items (if any). Refer to the examples below.

Example (with subordinate items):

9951 – 9961
CTR TK PUMP (affected).....OFF
Do not open the WING X FEED valve.

OUTR TK XFR.....ON

In this example, the effectivity 9951 - 9961 applies to the first procedural step (CTR TK PUMP.....) and the further indented/subordinate step (Do not...). The effectivity does not apply to the next equivalently indented step (OUTR TK XFR.....).

Example (without subordinate items):

Using ship number:

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9951 – 9961
CTR TK PUMP (affected).....ON
OUTR TK XFR.....OFF

In this example, the effectivity 9951 - 9961 applies to the first procedural step (CTR TK PUMP .....) only. The effectivity does not apply to the next procedural step (OUTR TK XFR .....).

Using model number:

88
9201-9219
ELECTRICAL POWER panel ..... Set

This notation is used to show that the material applies to all 88s and MD-90 ships 9201-9219.

When aircraft effectivities are centered immediately below a checklist title, the entire checklist applies to the listed aircraft. In the following example, the FUEL L + R CTR PUMPS LO PR checklist is applicable to 9951-9961 only:

FUEL L + R CTR PUMPS LO PR
9951-9961

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General

The following abbreviations may be found throughout the manual. Some abbreviations may also appear in lowercase letters. Abbreviations having very limited use are explained in the chapter where they are used. Since this list is compiled across several fleets, there may be some abbreviations that do not apply to this specific fleet.

A	
ABV	Above
AC	Alternating Current or Aircraft
ACARS	Aircraft Communications Addressing and Reporting System
ACE	Actuator Control Electronics
ACP	Audio Control Panel
ACT	Active
ADC	Air Data Computer
ADF	Automatic Direction Finder
ADI	Attitude Director Indicator
ADIRS	Air Data Inertial Reference System
ADIRU	Air Data Inertial Reference Unit
ADM	Air Data Module
AED	Automated External Defibrillator
AFB	Alternate Fuel Burn
AFDC	Autopilot Flight Director Computer
AFDS	Autopilot Flight Director System
AFE	Above Field Elevation
AFM	Airplane Flight Manual (FAA approved)
AFM - DPI	Airplane Flight Manual - Digital Performance Information
AFS	Automatic Flight System (Autopilot or Autothrottle)
A/G	Air/Ground
AGL	Above Ground Level
AH	Alert Height
AHRS	Attitude Heading Reference System
AI	Anti-Ice
AIL	Aileron
AIMS	Airplane Information Management System
ALFA	Safe Stall Margin Speed
ALT	Altitude
ALT ACQ	Altitude Acquire
ALT HOLD	Altitude Hold
ALTN	Alternate

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	Amplitude Modulation
AMI	Airline Modifiable Information
AMM	Aircraft Maintenance Manual
ANP	Actual Navigational Performance
ANT	Antenna
ANU	Aircraft Nose Up
AOA	Angle of Attack
AOC	Airline Operational Communication Data Link
A/P	Autopilot
APB	All Pilots Bulletin
APL	Airplane
APP	Approach
APU	Auxiliary Power Unit
AR	Authorization Required
ARINC	Aeronautical Radio, Incorporated
ARM	Aircraft Restrictions Manual
ARPT	Airport
ARR	Arrival
ART	Automatic Reserve Thrust
ASA	Autoland Status Annunciator
ASAP	Aviation Safety Action Program
ASI	Airspeed Indicator
ASR	Airport Surveillance Radar

ASYM	Asymmetry
A/T	Autothrottle
ATA	Actual Time of Arrival
ATC	Air Traffic Control
ATIS	Automated Terminal Information Service
ATM	Assumed Temperature Method
ATT	Attitude
AUTO	Automatic
AUTO–THROT	Autothrottle
AUX	Auxiliary
AVAIL	Available
AWABS	Automated Weight and Balance System
B	
BARO	Barometric
BAT	Battery
B/C or B/CRS or BAC or BCS	Back Course
BFO	Beat Frequency Oscillator
BITE	Built-In Test Equipment
BKR	Breaker
BLD	Bleed
BLW	Below
BRG	Bearing
BRT	Bright
BTL	Bottle

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BTL DISCH	Bottle Discharge (fire extinguisher)
BTMS	Brake Temperature Monitoring System
C	
C	Captain or Celsius or Center or Cool
CAA	Civil Aviation Authority
CADC	Central Air Data Computer
CALSEL	Call Select
CANC/RCL	Cancel/Recall
CAP	Capture
CAPT	Captain
CAWS	Central Aural Warning System
CB	Circuit Breaker
CCD	Cursor Control Device
CDFA	Continuous Descent Final Approach
CDS	Common Display System
CDU	Control Display Unit
CFIT	Controlled Flight Into Terrain
CG	Center of Gravity
CHKL	Checklist
CHR	Chronograph
CKD	Checked
CKT	Circuit
CL	Close
CLB	Climb
CLMP	Computer Lockout Manual Power
CLR	Clear
CMD	Command
CO	Company
COMM	Communication
COMP	Comparator
COMPT	Compartment
CON	Continuous
CONFIG	Configuration
CONT	Control
COOL	Cooling
CRM	Crew Resource Management
CRS	Course
CRT	Cathode Ray Tube
CRZ	Cruise
CTL	Control
CTR	Center
CWS	Control Wheel Steering
D	
DA	Decision Altitude
DA(H)	Decision Altitude (Height)
DC	Direct Current
DCU	Display Concentrator Unit
D/D	Direct Descent
DDA	Derived Decision Altitude (MDA +50 feet)
DDG	Dispatch Deviations Guide

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DEL	Delete
DEP	Departure
DEP ARR	Departure Arrival
DEPR	Depressurize
DES	Descent
DEU	Display Electronic Unit
DFCS	Digital Flight Control System
DFGC	Digital Flight Guidance Computer
DFGS	Digital Flight Guidance System
DH	Decision Height
DIFF	Differential
DIR	Direct
DISC	Disconnect
DISCH	Discharge
DK	Deck
DME	Distance Measuring Equipment
DN	Down
DP	Departure Procedures
DPC	Display Processing Computer
DSP	Display Select Panel
DSPL	Display
DTG	Distance to Go
DTW	Distance to Waypoint
DU	Display Unit

E	
EADI	Electronic Attitude Director Indicator
ECON	Economy
E/D	End of Descent
E/E	Electrical/Electronic
EEC	Electronic Engine Control
EFI	Electronic Flight Instruments
EFIS	Electronic Flight Instrument System
EGPWS	Enhanced Ground Proximity Warning System
EGT	Exhaust Gas Temperature
EHSI	Electronic Horizontal Situation Indicator
EICAS	Engine Indication and Crew Alerting System
EIS	Electronic Instrument System
ELEC	Electrical
ELEV	Elevator
EMER	Emergency
ENG	Engine
ENG OUT	Engine Out
ENT	Entry
EO or E/O	Engine Out
EOAP	Electronic Overhead Annunciation Panel
EPC	Electrical Power Center
EPR	Engine Pressure Ratio

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EQPT or EQUIP	Equipment
ETOPS	Extended Range Operation with Twin Engine Airplanes
ETP	Equal Time Point
EVAC	Evacuation
EXEC	Execute
EXT	Extend or External
F	
F	Fahrenheit
FAC	Final Approach Course
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FAF	Final Approach Fix
FAR	Federal Aviation Regulation
FB	Fleet Bulletin
FCC	Flight Control Computer
FCTL	Flight Control
FCTM	Flight Crew Training Manual
FD, F/D or FLT DIR	Flight Director
FF	Fuel Flow
FFM	Force Fight Monitor
FGCP	Flight Guidance Control Panel
FGS	Flight Guidance System
FILT	Filter
FIR	Flight Information Region
FL CH or FLCH	Flight Level Change
FLT	Flight
FLT CTRL	Flight Control
FLPRN	Flaperon
FMA	Flight Mode Annunciator
FMC	Flight Management Computer
FMS	Flight Management System
F/O or F O	First Officer
FOM	Flight Operations Manual
FOQA	Flight Operations Quality Assurance
FPA	Flight Path Angle
FPM	Feet Per Minute
FPV	Flight Path Vector
FREQ	Frequency
F/S	Fast/Slow
FT	Feet
FWD	Forward
FWSOV	Fire Wall Shut Off Valve
FX	Fix
G	
GA	Go–Around
GEN	Generator
GLS	GNSS Landing System
GMT	Greenwich Mean Time
GND	Ground
GNSS	Global Navigation Satellite System

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GP or G/P	Glide Path
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GS	Ground Speed
G/S	Glide Slope
GW	Gross Weight
H	
HAA	Height Above Airport
HAT	Height Above Touchdown
HDG	Heading or Hydraulic Driven Generator
HDG REF	Heading Reference
HDG SEL	Heading Select
HF	High Frequency
HGS	Head-Up Guidance System (HGS® is a registered trademark of Flight Dynamics)
HI	High
HLD	Hold
HPA	Hectopascals
HPSOV	High Pressure Shut Off Valve
HSI	Horizontal Situation Indicator
HUD	Head-Up Display
HYD	Hydraulic

I	
IAF	Initial Approach Fix
IAN	Integrated Approach Navigation
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IDENT	Identification
IFE	In-Flight Entertainment System
IFR	Instrument Flight Rules
IGN	Ignition
IGS	Instrument Guidance System
ILS	Instrument Landing System
IM	Inner Marker
IMC	Instrument Meteorological Conditions
IMPF	Improved Performance
IN	Inches
INBD	Inboard
IND	Indicator
IND LTS	Indicator Lights
INOP	Inoperative
INIT	Initialization
INSTR	Instrument
INT or INTPH	Interphone
INTC	Intercept
INTC CRS	Intercept Course
IP	Instructor Pilot

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IQ	Initial Qualification
IRS	Inertial Reference System
IRU	Inertial Reference Unit
ISA	International Standard Atmosphere
ISDU	Inertial System Display Unit
ISFD	Integrated Standby Flight Display
ISLN	Isolation
J	
JAA	Joint Aviation Authority
K	
K or KTS	Knots
KCAS	Knots Calibrated Airspeed
KGS	Kilograms
KIAS	Knots Indicated Airspeed
L	
L	Left
LAT	Latitude
LBS	Pounds
LD	Load
LDA	Localizer-type Directional Aid
LDG	Landing
LDG ALT	Landing Altitude
LE	Leading Edge
LIM	Limit
LIM SPD	Limit Speed
LKD	Locked
L NAV or LNAV	Lateral Navigation
LOC	Localizer
LOC-BC	Localizer Back Course
LOE	Line Oriented Evaluation
LOM	Locater Outer Marker
LON	Longitude
LPR	Landing Performance Request
LRC	Long Range Cruise
LRU	Line Replaceable Unit
LSK	Line Select Key
LT	Light
LWR CTR	Lower Center
LWR DSPLY or LWR DSPL	Lower Display
M	
M	Mach
MAG	Magnetic
MAHP	Missed Approach Holding Point
MAN	Manual
MAP	Missed Approach Point
MASI	Mach/Airspeed Indicator
MAX	Maximum
MCA	Minimum Crossing Altitude
MCC	Maintenance Control Center
MCDU	Multi-function Control and Display Unit
MCO	Maintenance Carry Over

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MCP	Mode Control Panel
MCT	Maximum Continuous Thrust
MDA	Minimum Descent Altitude
MDA(H)	Minimum Descent Altitude (Height)
MDM	Mechanical Dispatch Manual
MEA	Minimum Enroute Altitude
MEL	Minimum Equipment List
MFD	Multifunction Display
MHZ	Megahertz
MIC	Microphone
MIN	Minimum
MKR	Marker
MLS	Microwave Landing System
MM	Middle Marker
MMO	Maximum Mach Operating Speed
MNPS	Minimum Navigation Performance Specification
MOCA	Minimum Obstruction Clearance Altitude
MOD	Modify
MORA	Minimum Off Route Altitude
MSA	Minimum Safe Altitude
MSG	Message
MSGS RCVD	Messages Received
MSL	Mean Sea Level
MTRS	Meters
MVA	Minimum Vectoring Altitude
MUH	Minimum Use Height
N	
N	Normal
NADP	Noise Abatement Departure Procedures
NAR	North American Route
NASA	National Aeronautics and Space Administration
NATS	North Atlantic Track System
NAV	Navigation
NAV RAD	Navigation Radio
ND	Navigation Display
NLT	No Later Than
NM	Nautical Mile(s)
NNC	Non-Normal Checklists
NNM	Non-Normal Maneuvers
NPS	Navigation Performance Scales
NORM	Normal
NTSB	National Transportation Safety Board
N1	Low Pressure Rotor Speed
N2	High Pressure Rotor Speed (Pratt & Whitney and GE engines) or Intermediate Pressure Rotor Speed (Rolls Royce Engines)

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N3	High Pressure Rotor Speed (Rolls Royce Engines)
O	
OAP	Overhead Annunciator Panel (a.k.a. EOAP)
OAT	Outside Air Temperature
OCC	Operations Control Center
ODM	Operational Data Manual
OFST	Offset
OHU	Overhead Unit
OM	Outer Marker
OP	Open
OUTBD DSPL	Outboard Display
OVHD	Overhead
OVHT	Overheat
OVRD	Override
OVSPD	Overspeed
OXY or O2	Oxygen
P	
PA	Passenger Address
PAPI	Precision Approach Path Indicator
PAR	Precision Approach Radar
PASS	Passenger
PBE	Protective Breathing Equipment
PCP	Pilot Call Panel
PDC	Pitch Data Computer or Performance Data Computer or Pre-Departure Clearance
PERF	Performance
PERF INIT	Performance Initialization
PES	Pitch Enhancement System
PF	Pilot Flying
PFAF	Precision Final Approach Fix
PFC	Primary Flight Computer
PFD	Primary Flight Display
PI	Performance Inflight
PIP	Product Improvement Package
PLI	Pitch Limit Indicator
PM	Pilot Monitoring
PMC	Power Management Control
PNL	Panel
PNF	Pilot Not Flying
POS	Position
POS INIT	Position Initialization
POS REF	Position Reference
PPI	Planned Position Indicator
PPOS	Present Position
PRES or PRESS	Pressure
PREV	Previous

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PRI	Primary
PRAIM	Predictive Receiver Autonomous Integrity Monitoring
PROG	Progress
PROX	Proximity
P/RST	Push To Reset
PRV	Pressure Regulating Valve
PSI	Pounds Per Square Inch
PTH	Path
PTT	Push To Talk
PTU	Power Transfer Unit
PWR	Power
PWS	Predictive Windshear System
Q	
Q	Quantity
QFE	Local Station Pressure
QNH	Altimeter Setting
QRH	Quick Reference Handbook
QTY	Quantity
R	
R	Right
RA	Radio Altitude or Resolution Advisory
RAD	Radio
RAS	Remote Access System
RAT	Ram Air Temperature or Ram Air Turbine
RATOW	Runway Allowable Takeoff Weight
RCL	Request for Clearance
RDMI	Radio Distance Magnetic Indicator
REC	Recorder
RECIR or RECIRC	Recirculation
REF	Reference
RET	Retract
REV	Reverse
RF	Radius-to-Fix (RF) Legs or Refill
RMI	Radio Magnetic Indicator
RON	Remain Overnight
RNAV or RNV	Area Navigation
RNP	Required Navigational Performance
RPL	Rudder Pressure Limiter
RPM	Revolutions Per Minute
RPR	Rudder Pressure Reducer
RSEP	Rudder System Enhancement Program
RST	Reset
RSVR	Reservoir
R/T	Radio Transmit
RTE	Route
RTO	Rejected Takeoff
RTP	Radio Tuning Panel
RUD	Rudder
RVR	Runway Visual Range
RVSM	Reduced Vertical Separation Minimum

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S	
SAAAR	Special Aircraft and Aircrew Authorization Required
SAARU	Secondary Attitude Air Data Reference Unit
SAT	Static Air Temperature or Satellite
SB	Service Bulletin
S/B	Speedbrake
S/C	Step Climb
SDF	Simplified Directional Facility
SEI	Standby Engine Indicator
SEL	Select
SELCAL	Selective Calling
SENS	Sensitivity
SERV	Service
SG	Symbol Generator
SID	Standard Instrument Departure
SMGCS	Surface Movement and Guidance Control System
SMS	Safety Management System
SPD	Speed
SPDBRK	Speedbrake
STA	Station
STAB	Stabilizer
STAR	Standard Terminal Arrival Route
STAT	Status
STBY	Standby
STD	Standard
SYS	System
T	
T or TRU	True
T or TK or TRK	Track (to a Navaid)
TA	Traffic Advisory
TAA	Terminal Arrival Area
TACAN	Tactical Air Navigation
TAC	Thrust Asymmetry Compensation
TAI	Thermal Anti–Ice
TAS	True Airspeed
TAT	Total Air Temperature
T/C	Top of Climb
TCA	Terminal Control Area
TCAS	Traffic Alert and Collision Avoidance System
T/D	Top of Descent
TDZ	Touch Down Zone
TDZE	Touch Down Zone Elevation
TE	Trailing Edge
TEM	Threat Error Management
TEMP	Temperature
TERP	Terminal Instrument Procedures
TERR	Terrain
TFC	Traffic
TFR	Transfer

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THR	Throttle or Thrust
THR HOLD	Throttle Hold
TMC	Thrust Management Computer
TMI	Track Message Identifier
TMSP	Thrust Mode Select Panel
TO or T/O	Takeoff
TOC	Top of Climb
TOD	Top of Descent
TO/GA	Takeoff/Go–Around
TOPR	Takeoff Performance Request
TPC	Tactical Pilotage Charts
TR	Traffic Resolution
TRK	Track
TRP	Thrust Rating Panel
TRU	Transformer Rectifier Unit
TURB	Turbine or Turbulence
U	
UNLKD	Unlocked
UNSCHD or UNSCHED	Unscheduled
UPR DSPL	Upper Display
U.S.	United States
USB	Upper Side Band
UTC	Universal Time Coordinated
UTIL	Utility

V	
VA	Design maneuvering speed
VAL	Valve
VANP	Vertical Actual Navigational Performance
VASI	Visual Approach Slope Indicator
VDP	Visual Descent Point
VEF	Speed at Engine Failure
VERT	Vertical
VFR	Visual Flight Rules
VG	Vertical Gyro
VHF	Very High Frequency
VIB	Vibration
VLOF	Lift Off Speed
VLV	Valve
VMC	Visual Meteorological Conditions
VMCA	Minimum Control Airspeed Single Engine Minimum Control Airspeed
VMCG	Minimum Control Speed Ground
VMO	Maximum Operating Speed
V NAV or VNAV	Vertical Navigation
VOR	VHF Omnidirectional Range
VP	Tire Hydroplaning Speed
VR	Rotation Speed

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VREF	Reference Speed
VRNP	Vertical Required Navigation Performance
V/S	Vertical Speed
VSCF	Variable Speed Constant Frequency
VSD	Vertical Situation Display
VSI	Vertical Speed Indicator
VTK	Vertical Track
V1	Takeoff Decision Speed
V1 (MCG)	Minimum V1 for Control on the Ground
V2	Scheduled Takeoff Target Speed
W	
W	Warm
WATRS	Western Atlantic Route System
WDR	Weight Data Record
WGS-84	World Geodetic System of 1984
WHL	Wheel
WPT	Waypoint
WT	Weight
WXR	Weather Radar
X	
X–FEED	Crossfeed
XPDR or XPNDR	Transponder
XTK	Cross Track

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Revision Notification Transmittal Letter

To: All holders of Delta Air Lines, Inc. Operations Manuals.

Subject: Operations Manual Revision.

This revision reflects the most current information available to Delta Air Lines, Inc. through the subject revision date. General information below explains the use of revision bars to identify new or revised information.

Revision Record

No.	Revision Date	Date Filed
0	January 16, 2014	
2	May 20, 2016	

No.	Revision Date	Date Filed
1	October 23, 2014	
3	September 12, 2016	

General

Delta Air Lines, Inc. issues operations manual revisions to provide new or revised procedures and information. Formal revisions also incorporate appropriate information from previously issued Fleet Bulletins.

The revision date is the date the revision material is distributed and considered current. EFB revision downloads and/or flight deck distribution should be accomplished as soon as possible, but may take as much as 21 days after the revision date for completion.

Revisions include a Transmittal Letter, Revision Record, Revision Highlights, and a List of Effective Pages. Use the information on the new Revision Record to review the revised operations manual content.

Revision Highlights

Pages containing revised technical and non-technical material have revision bars associated with the changed text or illustration.

Chapter PT - Preface

Section 2 - Introduction

Corrections to the Manual

PT.2.3 - Updated reference to the Deltanet.

PT.2.3 - Updated pathway to location of PCR.

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Warnings, Cautions, and Notes

PT.2.4 - Updated Warnings, Cautions, and Notes section for standardization.

Aircraft Effectivities

PT.2.5 - Added section for standardization.

Section 4 - Revision Record

PT.4.1 - Revised to match the electronic-only methodology.

PT.4.1 - Updated for standardization.

Chapter 1 - General Information

Pushback

1.3 - Updated flow to match current procedure.

Start/Delayed Start

1.4 - Updated switch nomenclature to match panel.

After Start / Delayed After Start

1.5 - Updated flow and switch nomenclature to match current procedure.

Taxi

1.6 - Updated switch nomenclature to match panel.

Before Takeoff

1.7 - Updated flow and switch nomenclature to match current procedure.

After Takeoff

1.8 - Updated switch nomenclature to match panel.

Climb

1.9 - In graphic, added steps for PM to accomplish.

Descent

1.10 - Updated flow and switch nomenclature to match current procedure.

Approach

1.11 - Updated switch nomenclature to match panel.

Landing

1.12 - Updated switch nomenclature to match panel.

After Landing

1.13 - Updated flow and switch nomenclature to match current procedure.

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Shutdown

1.14 - Modified switch nomenclature to match panels.

Chapter 5 - Approach and Missed Approach

ILS PRM Approach

5.26 - Under PRM Breakout Maneuver, revised table to match the Vol. 1, NOI.3 material.

Chapter 6 - Landing

VASI Landing Geometry

6.2 - Changed wording to "flight deck".

Directional Control and Braking during Landing Roll

6.14 - Under Directional Control and Braking During Landing, added caveat for a dry runway.

Factors Affecting Landing Distance

6.14 - Under Factors Affecting Landing Distance, deleted sentence for actual stopping distances.

6.14 - Under Factors Affecting Landing Distance, deleted Note for spoilers fully deployed.

6.14 - Under Factors Affecting Landing Distance, added LPR as reference for landing distances.

6.15 - Updated information to include the LPR.

6.15 - Added Caution for non-Dry runways.

6.15 - Added Caution for allowing nosewheel touchdown.

6.15 - Revised Caution regarding resulting moment when using reverse thrust/rudder deflection for clarity.

6.16 - Add paragraph for MD-88 regarding adding reverse thrust to reduce stopping distance.

6.17 - Added sentence for steps to regain directional control if necessary.

Wheel Brakes

6.18 - Revised sentence for clarity.

6.19 - Added LPR as location for locating stopping distance information.

6.21 - Changed maximum reverse to 1.3 EPR reverse.

Reverse Thrust Operation

6.22 - Revised explanation of hand position on thrust levers.

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6.22 - Added condition of reverse asymmetry.

6.23 - Added Note for result of activation of emergency reverse thrust.

Chapter 7 - Maneuvers

Traffic Alert and Collision Avoidance System

7.24 - TCAS information replaced, partial incorporation of FB 16-04: TCAS Resolutional Advisory (RA) Policy Update.

Chapter 9 - Human Factors

CRM Skills

9.8 - Changed "Special Page" to "Company Page".

Chapter 10 - Selected References

Departure Procedures (DPs)

10.6 - Changed "10-7" to "Company".

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Preface — Chapter PT
List of Effective Pages - FAA Approved — Section 5

Page	Date
FCTM	
* Title Page	September 12, 2016
* PT.TOC.0.1-2	September 12, 2016
* PT.1.1-8	September 12, 2016
* PT.2.1-6	September 12, 2016
* PT.3.1-14	September 12, 2016
* PT.4.1-4	September 12, 2016
* PT.5.1-2	September 12, 2016
General Information (tab)	
* 1.TOC.1-2	September 12, 2016
* 1.1-30	September 12, 2016
Ground Operations (tab)	
* 2.TOC.1-2	September 12, 2016
* 2.1-42	September 12, 2016
Takeoff, Initial Climb (tab)	
* 3.TOC.1-2	September 12, 2016
* 3.1-34	September 12, 2016
Climb, Cruise, Descent, Holding (tab)	
* 4.TOC.1-2	September 12, 2016
* 4.1-26	September 12, 2016
Approach, Missed Approach (tab)	
* 5.TOC.1-4	September 12, 2016
* 5.1-74	September 12, 2016
Landing (tab)	
* 6.TOC.1-2	September 12, 2016
* 6.1-28	September 12, 2016

Page	Date
Maneuvers (tab)	
* 7.TOC.1-4	September 12, 2016
* 7.1-40	September 12, 2016
Non-Normal Operations (tab)	
* 8.TOC.1-4	September 12, 2016
* 8.1-40	September 12, 2016
Maneuvers (tab)	
* 9.TOC.1-2	September 12, 2016
* 9.1-18	September 12, 2016
Maneuvers (tab)	
* 10.TOC.1-2	September 12, 2016
* 10.1-34	September 12, 2016
Index (tab)	
* Index.1-8	September 12, 2016

* = Revised, Added, or Deleted

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General Information — Chapter 1
Table of Contents — Section TOC

Crew Resource Management 1.1

Flow Pattern Diagram 1.1

Preflight 1.2
Pushback 1.3
Start/Delayed Start 1.4
After Start / Delayed After Start 1.5
Taxi 1.6
Before Takeoff 1.7
After Takeoff 1.8
Climb 1.9
Descent 1.10
Approach 1.11
Landing 1.12
After Landing 1.13
Shutdown 1.14

Speed Booklet Analysis 1.15

Minimum Maneuvering Speeds 1.16
Maneuver Margins 1.16

Command Speed 1.17

Takeoff 1.17
Climb, Cruise and Descent 1.17
Approach 1.17
Landing 1.17
Non-Normal Conditions 1.18

Reference Speeds 1.19

Setting 1.19

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Airspeed Reference Bug Setting 1.19

Fast/Slow Display Use 1.20

Thrust Management 1.21

Maximum Thrust 1.21

Recommended Rudder Trim Technique 1.21

Drag Factors Due to Trim Technique 1.21

Primary Rudder Trim Technique 1.22

Alternate Rudder Trim Technique 1.22

RNAV Operations 1.23

RNP and ANP Definitions 1.23

Basic RNP Concept 1.23

Radius-to-Fix (RF) Legs 1.23

Autoflight Guidelines 1.24

Automatic Flight 1.24

DFGS Guidelines 1.25

MCP Altitude Setting Techniques Using VNAV 1.26

MAP Failure 1.27

Flight in Moderate to Heavy Rain, Hail, or Sleet 1.27

Turbulent Air Penetration 1.27

Ice Crystal Icing 1.28

Recognizing Ice Crystal Icing Weather 1.29

Avoiding Ice Crystal Icing Weather 1.30

Suspected Ice Crystal Icing 1.30

Wing Anti-Ice Operation - In Flight 1.30

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Crew Resource Management

The nature of training requires that pilots have a clear understanding of human factors in chapter 9 prior to training.

The “train the way you fly” philosophy requires that pilots have a good understanding of CRM and Delta Air Lines’ Threat and Error Management (TEM) model. TEM is integrated into every training program at Delta Air Lines. Pilots are expected to perform the following TEM actions during training:

- Conduct effective briefings to deal with expected threats
- Proactively identify threats and ways to manage them
- Identify errors and ways to manage them as they are detected
- Mitigate the consequences of an error after detection.

In addition to TEM strategies, pilots will use the following CRM tools during training:

- Situational awareness
- Decision making
- Planning
- Communication
- Workload management
- Professional management.

Flow Pattern Diagram

Flow patterns are based on their respective procedure and follow the order of the aircraft-specific tasks listed in the procedure. Flow pattern diagrams are a visual training aid used to facilitate accomplishing the steps listed in the respective procedure.

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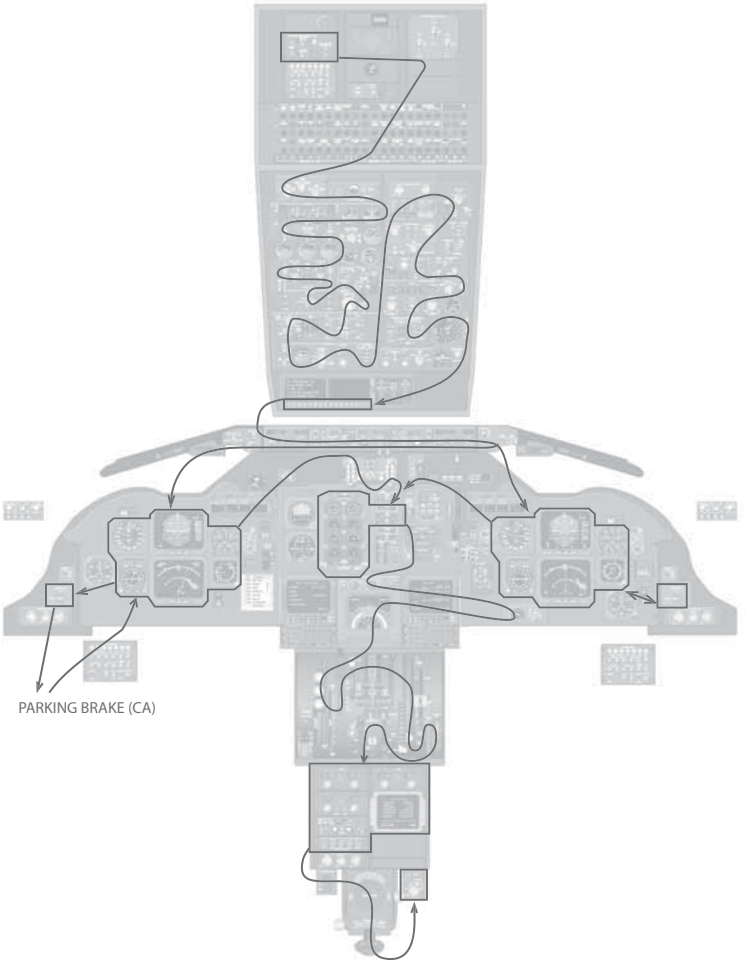
Preflight



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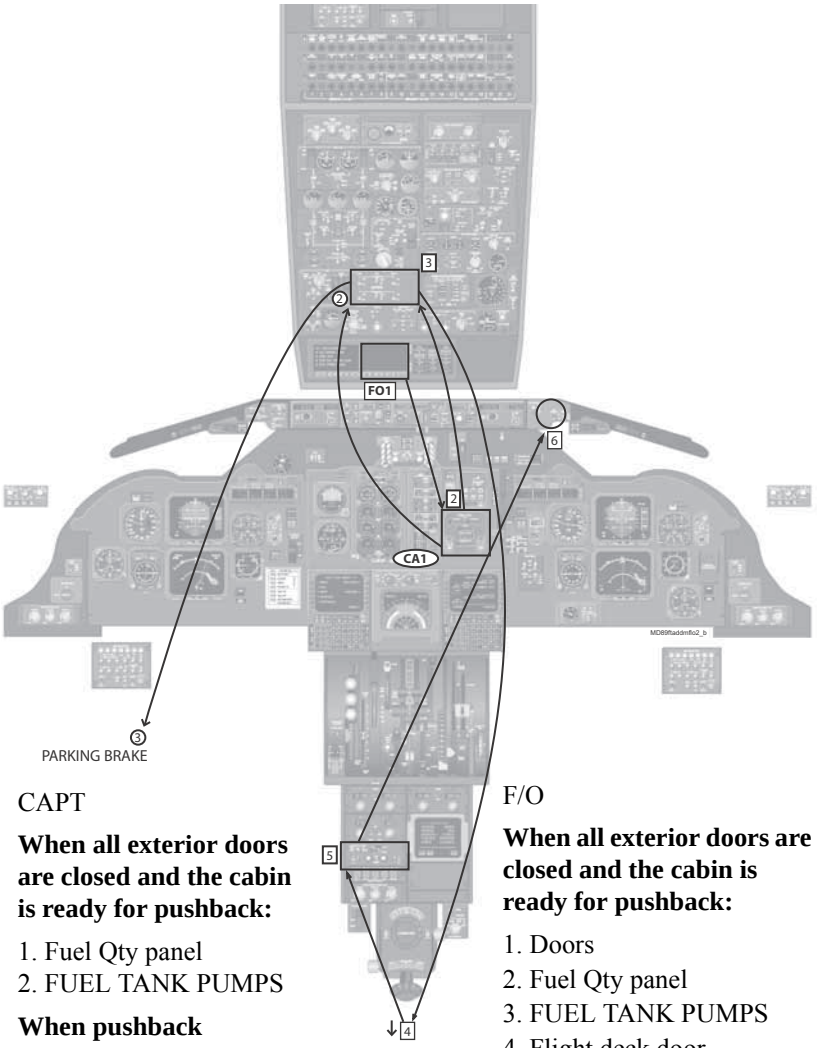
Pushback



CAPT

When all exterior doors are closed and the cabin is ready for pushback:

1. Fuel Qty panel
2. FUEL TANK PUMPS

When pushback clearance is received:

3. Parking brake - OFF

F/O

When all exterior doors are closed and the cabin is ready for pushback:

1. Doors
2. Fuel Qty panel
3. FUEL TANK PUMPS
4. Flight deck door
5. Transponder - ALT ON/XPNDR/XPDR

When pushback clearance is received:

6. ANTI-COLLISON - ON

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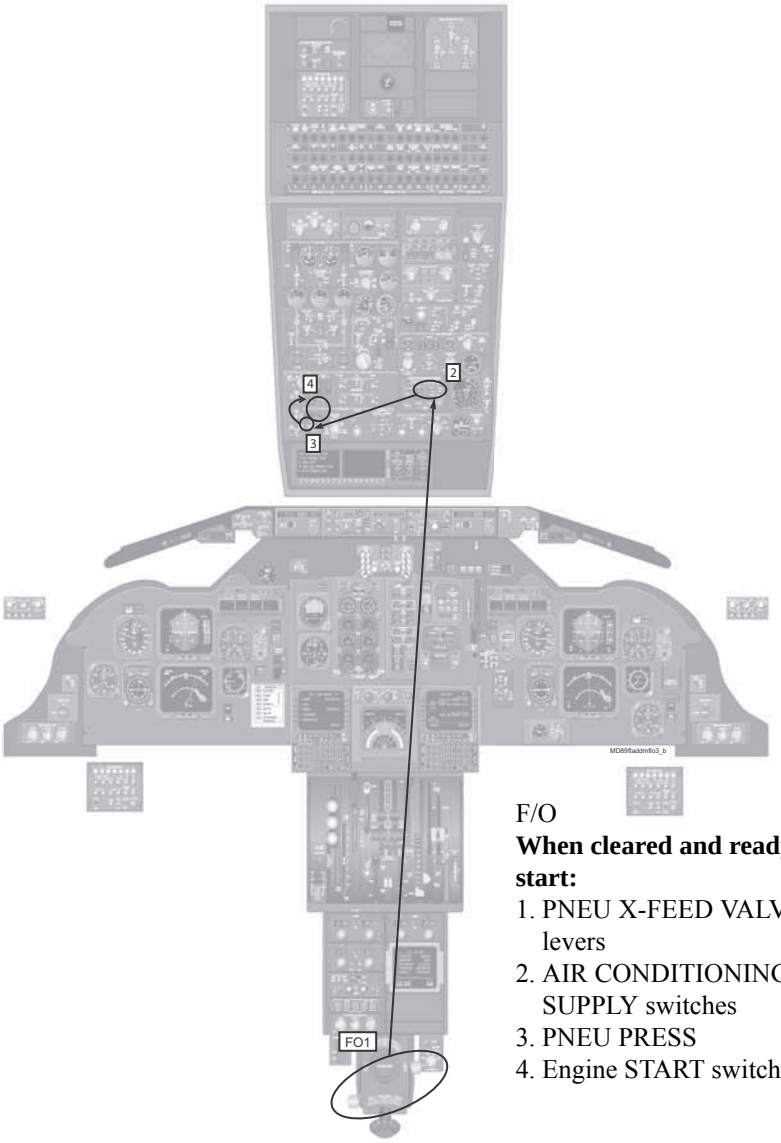
Start/Delayed Start



F/O

When cleared and ready to start:

1. PNEU X-FEED VALVE levers
2. AIR CONDITIONING SUPPLY switches
3. PNEU PRESS
4. Engine START switch

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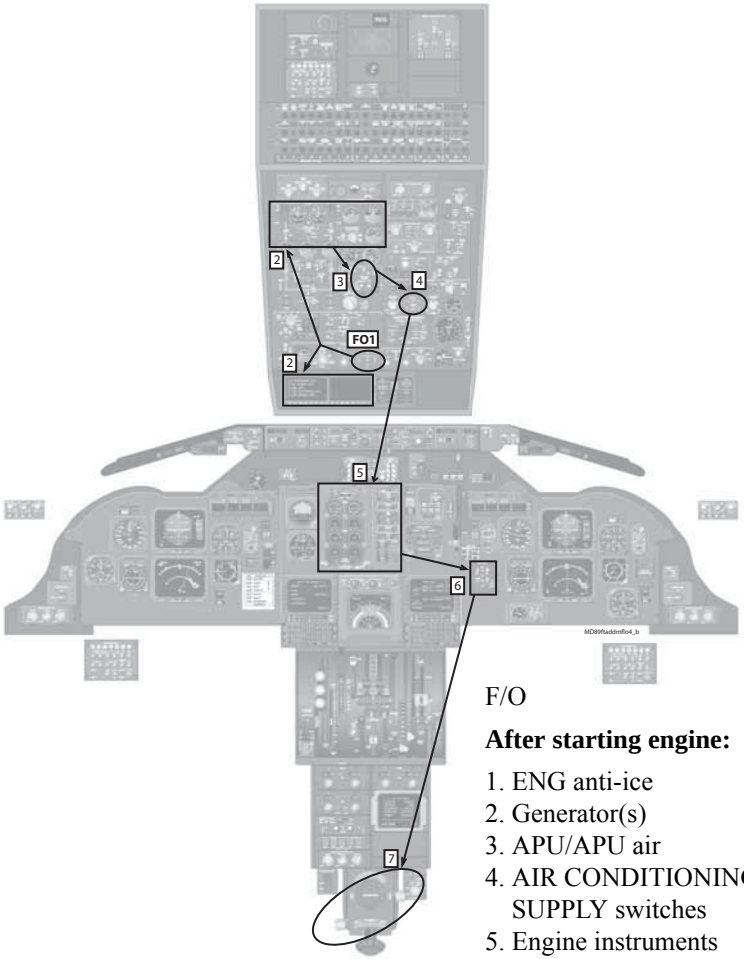
After Start / Delayed After Start



F/O

After starting engine:

1. ENG anti-ice
2. Generator(s)
3. APU/APU air
4. AIR CONDITIONING SUPPLY switches
5. Engine instruments
6. Hydraulic panel
7. PNEU X-FEED VALVE levers

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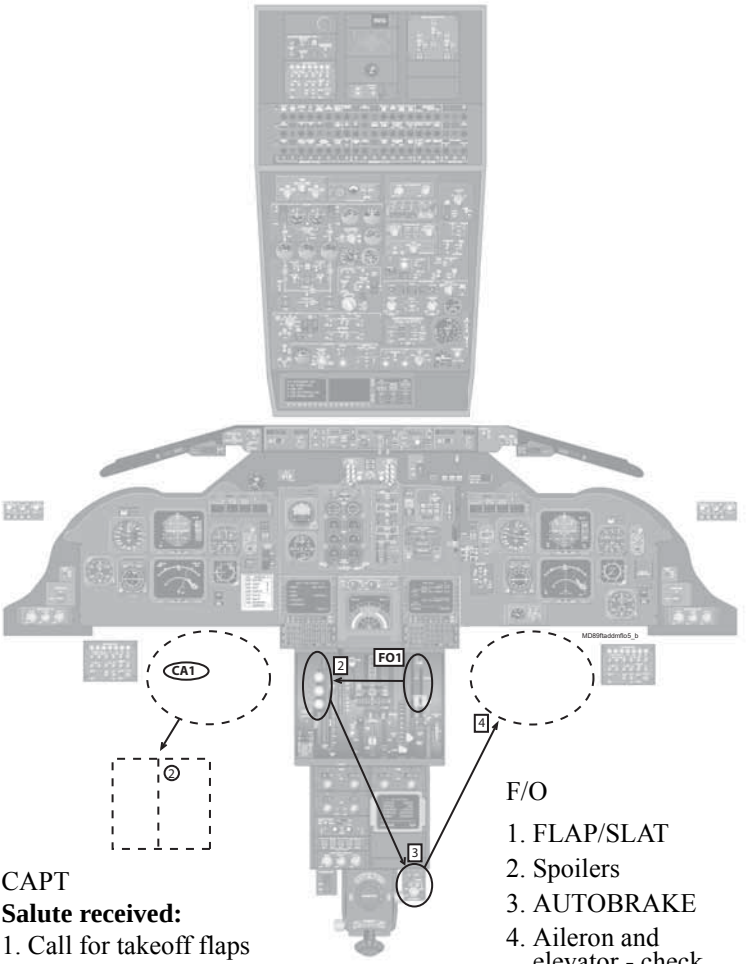
Taxi



CAPT

Salute received:

1. Call for takeoff flaps
2. Rudder - check

F/O

1. FLAP/SLAT
2. Spoilers
3. AUTOBRAKE
4. Aileron and elevator - check

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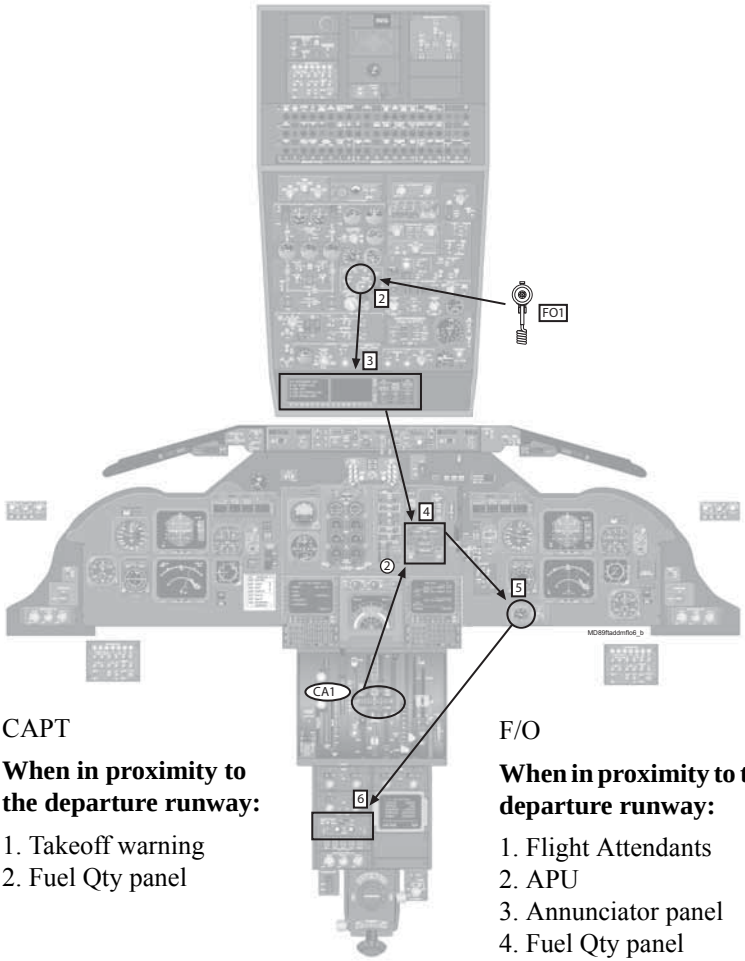
Before Takeoff



CAPT

When in proximity to the departure runway:

1. Takeoff warning
2. Fuel Qty panel

F/O

When in proximity to the departure runway:

1. Flight Attendants
2. APU
3. Annunciator panel
4. Fuel Qty panel
5. BRAKE TEMP
6. Transponder TA/RA

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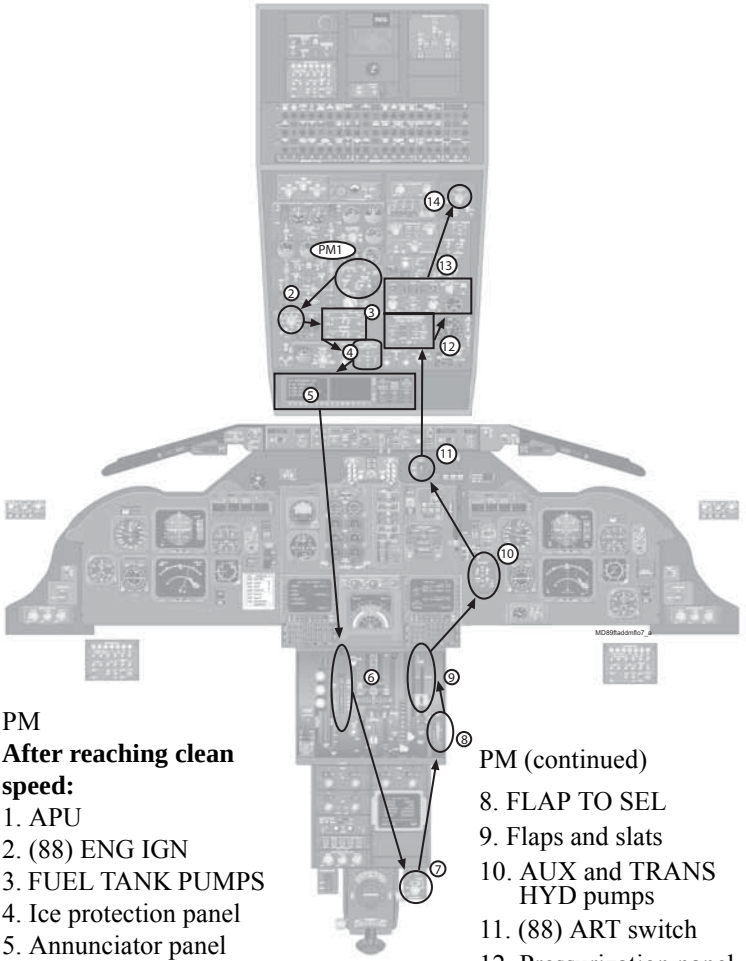
After Takeoff



PM

After reaching clean speed:

1. APU
2. (88) ENG IGN
3. FUEL TANK PUMPS
4. Ice protection panel
5. Annunciator panel
6. Spoilers
7. AUTOBRAKE

PM (continued)

8. FLAP TO SEL
9. Flaps and slats
10. AUX and TRANS HYD pumps
11. (88) ART switch
12. Pressurization panel
13. AIR CONDITIONING panel
14. ENG SYNC

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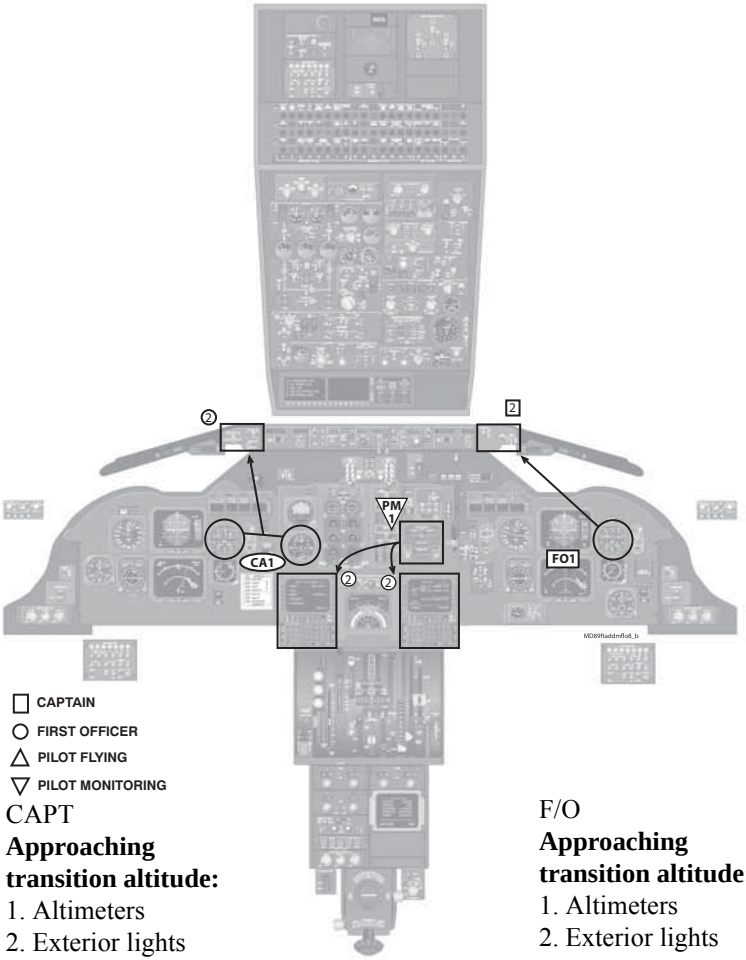
Climb



CAPT
Approaching transition altitude:
1. Altimeters
2. Exterior lights

F/O
Approaching transition altitude:
1. Altimeters
2. Exterior lights

PM
Approaching transition altitude:
1. FUEL QTY
2. FMS

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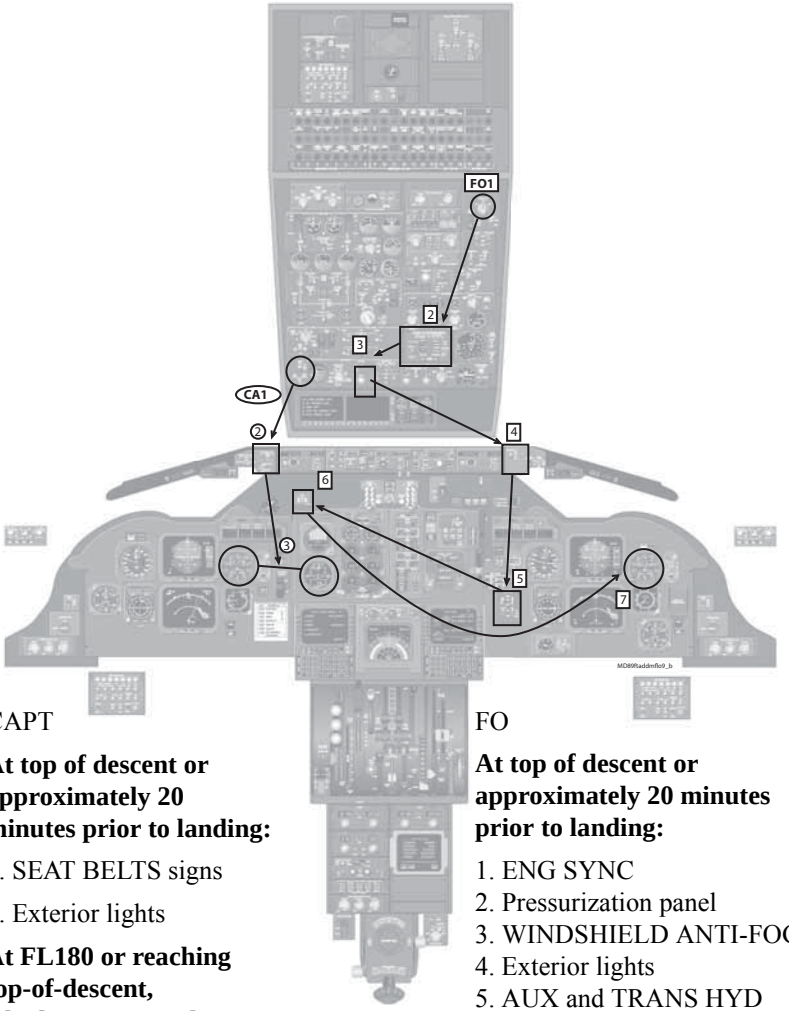
Descent



CAPT

At top of descent or approximately 20 minutes prior to landing:

1. SEAT BELTS signs
2. Exterior lights

At FL180 or reaching top-of-descent, whichever occurs later:

3. Altimeters

FO

At top of descent or approximately 20 minutes prior to landing:

1. ENG SYNC
2. Pressurization panel
3. WINDSHIELD ANTI-FOG
4. Exterior lights
5. AUX and TRANS HYD pumps
6. BRAKE PRESS

At FL180 or reaching top-of-descent, whichever occurs later:

7. Altimeters

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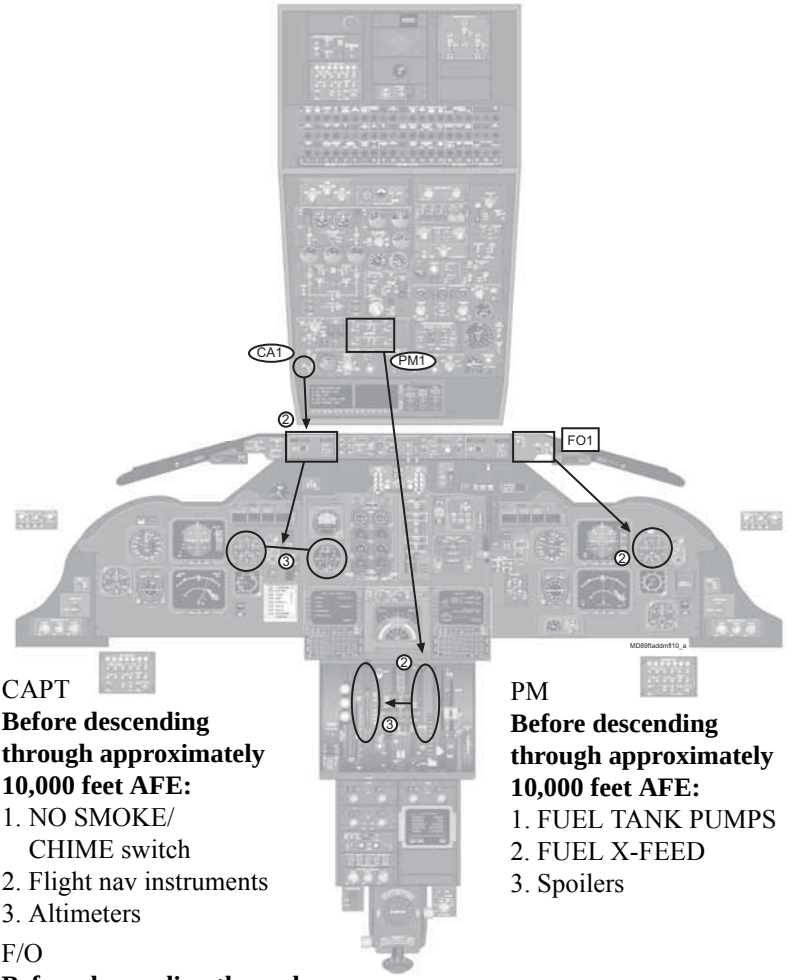
Approach



CAPT

Before descending through approximately 10,000 feet AFE:

1. NO SMOKE/ CHIME switch
2. Flight nav instruments
3. Altimeters

F/O

Before descending through approximately 10,000 feet AFE:

1. Flight nav instruments
2. Altimeters

PM

Before descending through approximately 10,000 feet AFE:

1. FUEL TANK PUMPS
2. FUEL X-FEED
3. Spoilers

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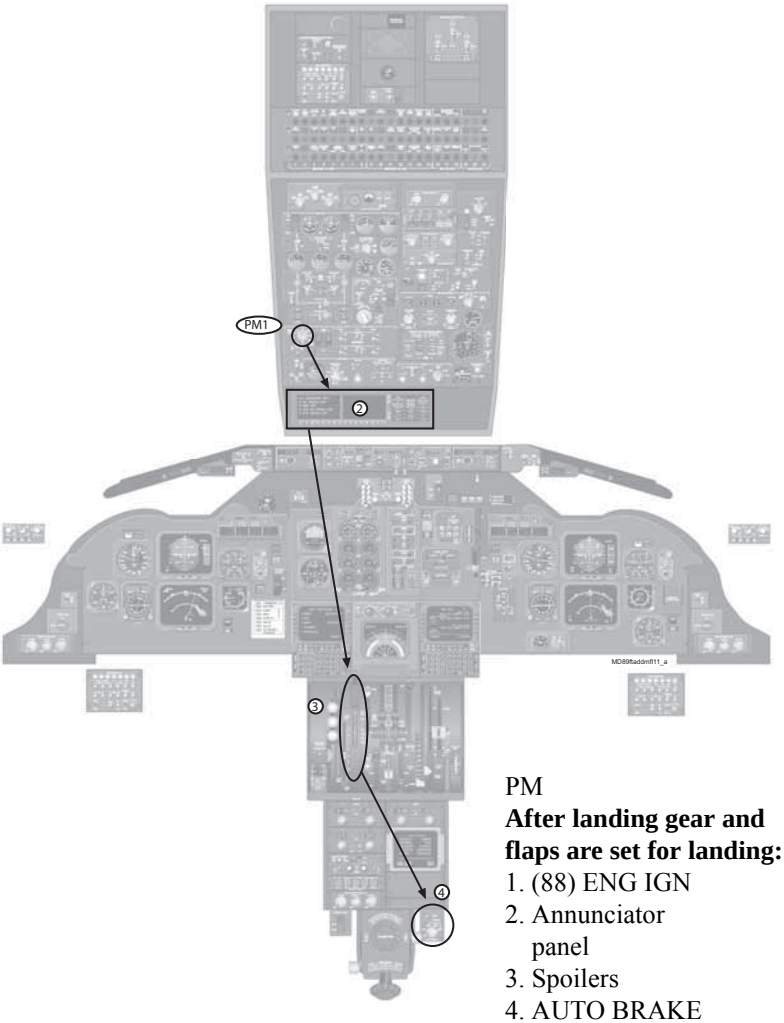
Landing



PM

After landing gear and flaps are set for landing:

1. (88) ENG IGN
2. Annunciator panel
3. Spoilers
4. AUTO BRAKE

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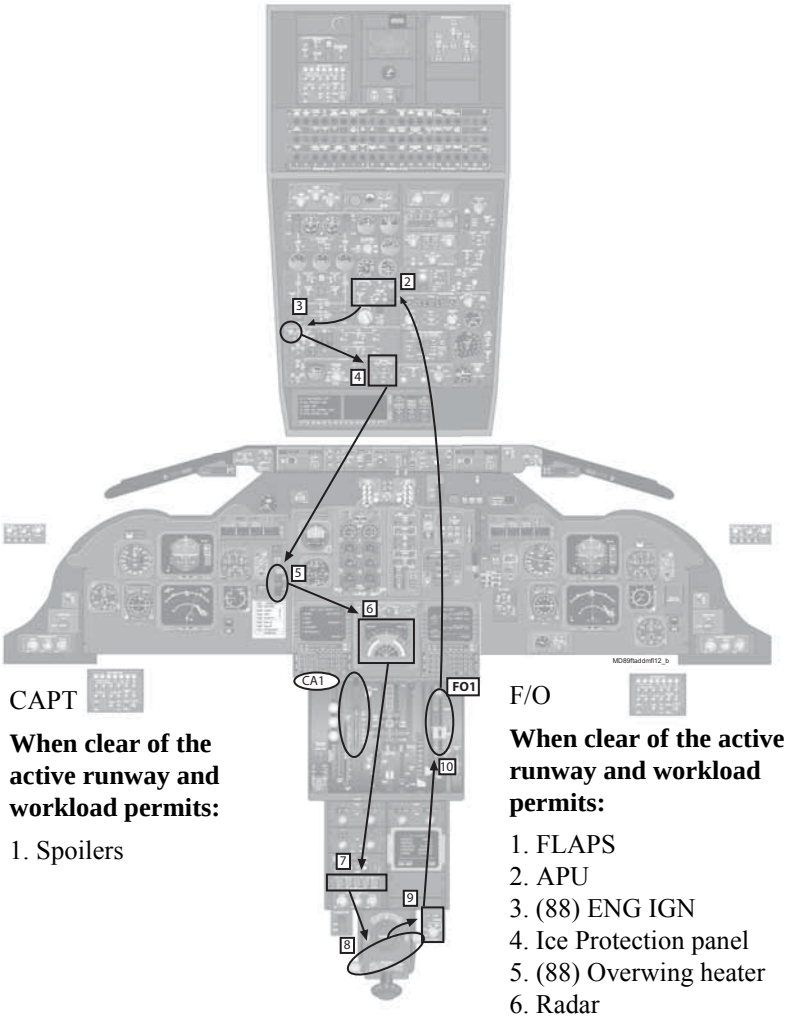
After Landing



CAPT

When clear of the active runway and workload permits:

1. Spoilers

F/O

When clear of the active runway and workload permits:

1. FLAPS
2. APU
3. (88) ENG IGN
4. Ice Protection panel
5. (88) Overwing heater
6. Radar
7. Transponder
   ALT ON/XPNDR/XPDR
8. PNEUMATIC X-FEED
9. AUTOBRAKE
10. SLATS

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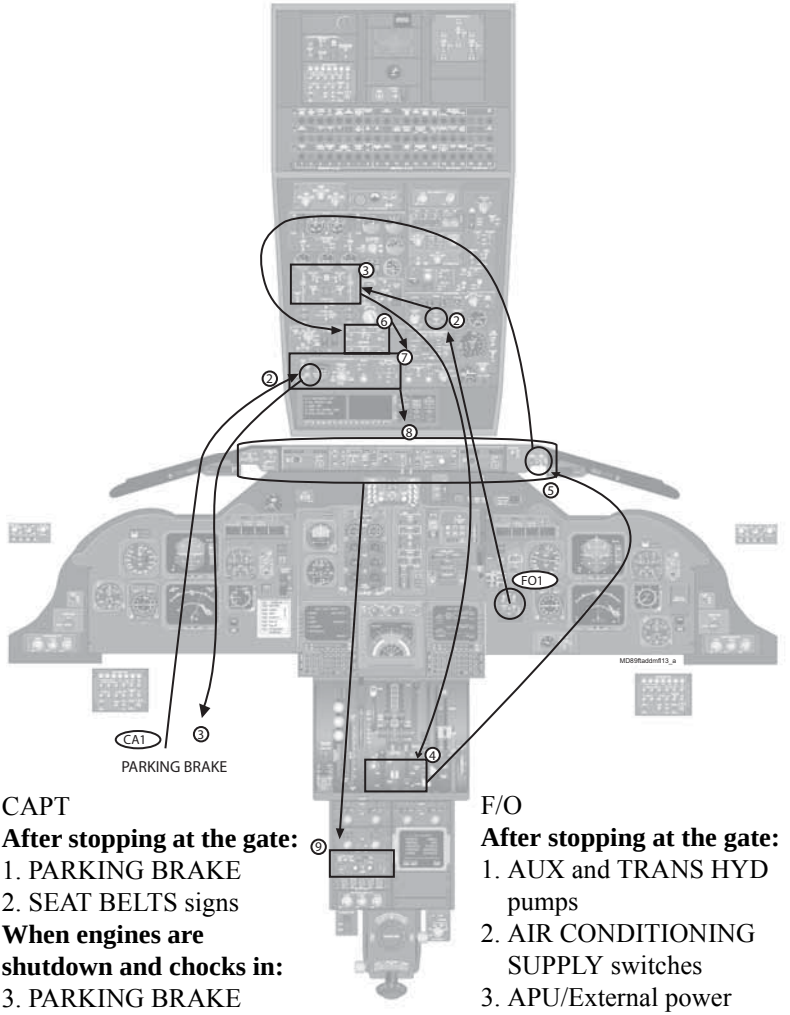
Shutdown



CAPT

After stopping at the gate:

1. PARKING BRAKE
2. SEAT BELTS signs

When engines are shutdown and chocks in:

3. PARKING BRAKE

F/O

After stopping at the gate:

1. AUX and TRANS HYD pumps
2. AIR CONDITIONING SUPPLY switches
3. APU/External power
4. (88) FUEL levers
   (90) FUEL switches
5. ANTI-COLLISION lights
6. FUEL TANK PUMPS
7. ICE PROTECT panel
8. FD switches
9. Transponder

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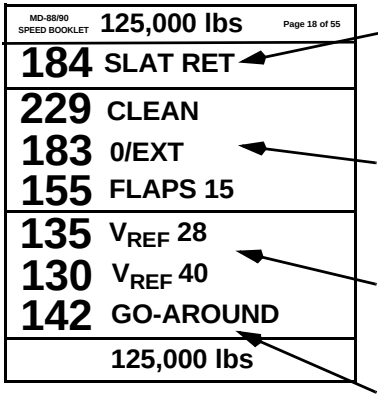
Speed Booklet Analysis

The speed booklet contains minimum maneuver and reference speeds for certain flap/slat configurations by aircraft weight in 2,500-pound increments. Use the closest weight for all reference speeds. The speed booklet maneuvering numbers are good for all altitudes and airspeeds. It is not necessary to reference the ODM for high altitude/hot temperature operations information.

Example Page	Description
	This is the minimum speed to safely retract the slats at this weight to maintain a safe stall margin. This speed is approximately 1.2 VS for a CLEAN wing. These are the maneuvering speeds for the associated configurations and represent approximately 1.4 to 1.5 VS. These are the reference speeds for approach and represent approximately 1.3 VS and assume minimum maneuvering is required after being established on final. This speed is approximately 1.25 VS for a Flaps 11 or 15 configuration and is the minimum climb safety speed for a go-around.

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Minimum Maneuvering Speeds

The minimum maneuvering speed additives are approximately 1.4 to 1.5 VS for each individual configuration. Minimum maneuvering speed additives for other flap configurations are shown below and in the speed booklet.

Configuration	Maneuvering Speed
Flaps 5	Flaps 15 Maneuvering + 20 knots
Flaps 11	Flaps 15 Maneuvering + 10 knots
Flaps 15	Flaps 15 Maneuvering
Flaps 23	Flaps 15 Maneuvering
Flaps 28 or 40	VREF + 10 knots

Note: For takeoff, do not exceed 15° of bank until at or above minimum maneuvering speed for the existing configuration. If maneuvering is a priority, delay the clean-up. V2 + 20 will provide a safe maneuvering speed for all takeoff flap settings. A maximum bank angle of 30 ° is permitted at V2 + 20 with takeoff flaps.

CAUTION: Operating close to the flap limit speed could cause inadvertent overspeed. Pilots are encouraged to operate the aircraft at least 10 knots below the placard speed.

Maneuver Margins

- There is a direct correlation between bank angle and load factor (gs) in level, constant speed flight. For example, 1.1g corresponds to 25° of bank, 1.3g ~ 40°, 2.0g ~ 60°.
- Stick shaker activates prior to actual stall speed.
- Flap retraction and extension schedules provide speeds that are close to minimum drag, and in a climb are close to maximum angle of climb speed.

Conditions Affecting Maneuver Margins to Stick Shaker

For a fixed weight and altitude, maneuver margin to stick shaker increases when airspeed increases. Other factors may or may not affect maneuver margin:

- Gross weight: Generally, maneuver margin decreases as gross weight increases. The base speed (V2 or VREF) increases with increasing weight. The speed additive is a smaller percent increase for heavier weights.
- Altitude: Generally, maneuver margin decreases with increasing altitude for a fixed airspeed.
- Temperature: The effect of a temperature change on maneuver margin is negligible.

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Command Speed

Command speed can be set to the desired speed by the FMS if using VNAV or manually using the MCP. Select Flaps/Slats, as needed, to maintain maneuvering capability.

Takeoff

Command speed remains set at V2 until changed by the pilot for acceleration and flap retraction or until a subsequent pitch mode is engaged

Climb, Cruise and Descent

Command speed is set to the appropriate speed by the FMS during VNAV operation or manually using the MCP. To prevent overspeeds, crews may need to adjust the IAS/MACH or Cost Index to maintain a 10 knot or greater buffer from Vmo/Mmo and flap placard speeds.

Approach

Command speed is set to the maneuver speed for the selected flap position by the FMS during VNAV operation or manually using the MCP.

Landing

When using the autothrottle, position command speed to VREF + 5 knots. Sufficient wind and gust protection is available with the autothrottle connected because the autothrottle is designed to adjust thrust rapidly when the airspeed drops below command speed while reducing thrust slowly when the airspeed exceeds command speed. In turbulence, the result is that average thrust is higher than necessary to maintain command speed. This results in an average speed exceeding command speed.

Autothrottle can be used to touchdown only on an autoland. Autothrottle must be disconnected no later than 50 feet RA on a manual landing.

If the autothrottle is disconnected, or is planned to be disconnected prior to landing, the recommended method for approach speed correction is to add 1/2 of the reported steady headwind component plus the full gust increment above the steady wind to the reference speed. The minimum command speed setting is VREF + 5 knots. One half of the reported steady headwind component can be estimated by using 50% for a direct headwind, 35% for a 45° crosswind, zero for a direct crosswind and interpolation in between.

When making adjustments for winds, the maximum command speed should not exceed VREF + 20 knots. The following table shows examples of wind additives with a runway heading of 360°.

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Reported Winds	Wind Additive	Approach Speed
360 at 16	8	VREF + 8 knots
Calm	0	VREF + 5 knots
360 at 20 Gust 30	10 + 10	VREF + 20 knots
060 at 24	6	VREF + 6 knots
090 at 15	0	VREF + 5 knots
090 at 15 Gust 25	0 + 10	VREF + 10 knots

Note: Do not apply wind additives for tailwinds. Set command speed at VREF + 5 knots (autothrottle engaged or disconnected).

Wind Component

Maximum gust velocity and least favorable direction will be used to compute the crosswind component.

Steady state wind velocity will be used to compute the headwind or tailwind component.

Non-Normal Conditions

Speed adjustments for non-normal conditions are contained in the appropriate non-normal checklist. Some non-normal checklists will instruct the flight crew to refer to the ODM, Abnormal section for VREF speeds. The ODM depicts minimum maneuver speeds (15° AOB) for configurations not found in the speed booklet (Flaps 15°/Slats retract) and threshold speeds for various flap and slat configurations.

Note: Final approach speed is computed as VREF + wind additive. There is no automatic 5 knot additive.

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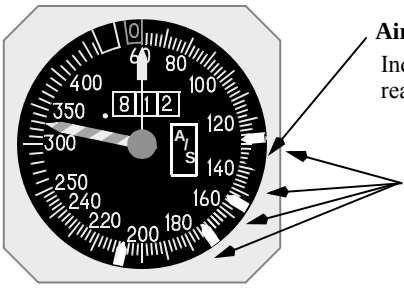
Reference Speeds

The following figure shows the positioning of the reference bug on the airspeed indicator for takeoff and approach.

Setting

Airspeed Reference Bug Setting



Airspeed Command Bug (Orange)
Indicates airspeed set in the SPD/MACH readout window of the MCP.

Airspeed Reference Bugs (4)
Movable pointers normally used to alert the pilot to specified airspeeds.

Takeoff

White movable reference airspeed bugs are set at V1, V2+20, slat retract, and clean (flaps up/slats retract) maneuvering speed. Command speed should be set at V2 using the MCP.

Landing

Position white reference airspeed bugs at clean maneuvering, flaps 0/slats extended, flaps 15 maneuvering, and go-around. Command speed should be set at final approach speed on the MCP.

Note: If a non-normal event precludes using all four reference bugs for approach and landing, position the bugs as appropriate for situation (i.e., double bug VREF and single bug clean speed during no flap/no slat approaches).

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Fast/Slow Display Use

The Fast/Slow (F/S) display indicates the deviation between actual and selected Mach or indicated airspeed for the range of selected airspeeds between maximum limit and minimum safe (Alpha speed) airspeed for the existing flap/slat configuration. If the selected speed lies outside of this range, the F/S displays the deviation between actual and maximum limit or minimum safe airspeed as applicable. There are some exceptions:

- Takeoff/Go-Around Mode (TO/GA): During takeoff or go-around (TO/GA selected), the F/S display indicates the speed deviation relative to the computed takeoff or go-around reference speeds.
- Retard Mode (RETD): In the RETD mode, the F/S display is removed.
- Flight Management System (FMS): With VNAV mode selected, the F/S display is referenced to the FMS target speed.
- Gust Integration (Autothrottles Engaged): During approach in turbulent conditions, with flaps set at landing configuration, an automatic increase in reference speed, up to a maximum of 5 knots, is added to compensate for wind gusts. The F/S display reflects this change in the reference speed.
- Windshear Encounter: During a detected windshear encounter, the F/S display indicates relative angle of attack (Alpha).

The F/S display provides useful information for predicting the actions of the autothrottle system. The autothrottle can rapidly increase power from idle to the TRP thrust limit (throttle burst) when the aircraft is allowed to enter a slow condition during the approach, as a result of high drag factor, lengthy engine spool-up time, speed command increase set by the pilot, or any combination of these. Conditions for throttle burst generally occur during approach when slowing and turning the aircraft. An indication of impending throttle burst is F/S pointer displacement well below the “on speed” diamond. Awareness of a throttle burst occurrence requires a pilot to monitor F/S pointer progress and aircraft speed to anticipate any delay of the engines to produce the required thrust. Manual throttle assistance can be used to prevent throttle burst when transitioning from a pitch-on-speed mode (IAS/CLMP) to a speed-on-throttle mode (V/S, ALT HLD). ILS Glideslope capture will “unclamp” the throttles and revert to a speed-on-throttle mode.

In the speed-on-throttle mode, the EPR xx and LOW limits are the extremes. Use of a throttle setting between these limits may require disconnecting the autothrottle and manually inputting the desired thrust prior to selecting a new speed. Re-engage the autothrottle when the F/S is centered again to maintain the selected speed.

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Subsequently, if the FMA shows the autothrottle is at the LOW Limit (the autothrottle system cannot reduce thrust at less than the LOW limit while the F/S pointer is centered on or above the "on speed" diamond), consider IAS/CLMP (not available with ILS/Autoland), increasing drag, or simply disconnecting the autothrottle and maintaining speed with manual throttle movement.

Refer to Vol. 2, 4.20, Autothrottle/Speed Control for additional information.

Thrust Management

Maximum Thrust

The term "maximum thrust" is used in various places in the FCTM and the Vol. 1. Maximum thrust is obtained:

- (88) by advancing the throttles to firewall.
- (90) by advancing the throttles through the ORT gate.

Recommended Rudder Trim Technique

This section describes two techniques for properly trimming the rudder. It is assumed that the aircraft is properly rigged and in normal cruise. The primary technique uses rudder trim only to level the control wheel and is an acceptable and effective method for trimming the aircraft. It is approximately equal to a minimum drag condition. This technique is usable for normal as well as many non-normal conditions. For some non-normal conditions, such as engine failure, this technique is the preferred method and provides near minimum drag.

The alternate technique may provide a more accurate trim condition when the roll is caused by a roll imbalance. In addition, this technique outlines the steps to be taken if the primary trim technique results in an unacceptable bank angle or excessive rudder trim. The alternate technique uses both rudder and aileron trim to neutralize a rolling condition using the bank pointer as reference.

Note: Large trim requirements may indicate the need for maintenance and should be noted in the aircraft log.

Drag Factors Due to Trim Technique

If the control wheel is displaced to the point of spoiler deflection a significant increase in aerodynamic drag results. Additionally, any rigging deviation that results in early spoiler actuation causes a significant increase in drag per unit of trim. These conditions result in increased fuel consumption. Small out-of-trim conditions affect fuel flow by less than 1%, if no spoilers are deflected.

Note: Aileron trim may be required for significant fuel imbalance, aircraft damage, or flight control system malfunctions.

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Primary Rudder Trim Technique

It is recommended that the autopilot remain engaged while accomplishing the primary rudder trim technique (using rudder trim only). After completing this technique, if the autopilot is disengaged, the aircraft should maintain a constant heading.

The following steps define the primary rudder trim technique:

- Set symmetrical thrust
- Balance fuel if required
- Ensure the autopilot is engaged in HDG HOLD and stabilized for at least 30 seconds
- Trim the rudder in the direction corresponding to the down (low) side of the control wheel until the control wheel indicates level. The indices on side of the control wheel should be used to ensure a level wheel condition. The aircraft is properly trimmed when the control wheel is level (zero index). As speed, gross weight, or altitude change, trim requirements may also change. In a proper trim condition, there may be a slight forward slip (slight bank angle indicated on the bank pointer) and a slight deflection of the slip/skid indicator, which is acceptable.

Alternate Rudder Trim Technique

The alternate rudder trim technique is used if the primary trim technique results in an unacceptable bank angle, excessive rudder trim, or if a more accurate dual axes trim is required.

The following steps define the alternate rudder trim technique:

- Set symmetrical thrust
- Balance fuel if required
- Verify rudder trim is zero
- Ensure the autopilot is engaged in HDG HOLD and stabilized for at least 30 seconds
- Trim the rudder in the direction corresponding to the down (low) side of the control wheel until the bank indicates level (no bank angle indicated on the bank pointer). Apply rudder trim incrementally, allowing the bank to stabilize after each trim input. Large trim inputs are more difficult to coordinate. The aircraft is properly trimmed when the bank angle on the bank pointer indicates zero. If the aircraft is properly rigged, the control wheel should indicate approximately level. The resultant control wheel condition indicates the true aileron (roll) trim of the aircraft being used by the autopilot.

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After completing the alternate rudder trim technique, if the autopilot is disengaged the aircraft may have a rolling tendency. Hold the wings level using the bank pointer as reference. Trim out any control wheel forces using the aileron trim knob. If properly trimmed, the aircraft holds a constant heading and the aileron trim reading on the wheel/column agrees with what was seen while the autopilot was engaged. Aileron trim inputs require additional time and should be accomplished prior to final approach.

RNAV Operations

Note: The MD-88/90 fleets are approved to operate as RNP 10 (50NM lateral separation) compliant in GOMEX airspace, but not other RNP 10 areas.

This section provides definitions of terms associated with RNAV and describes basic concepts to include phase of flight navigation for terminal (SIDs and STARs), en-route, and approach operations.

RNAV or area navigation is a method of navigation that allows aircraft to fly on any desired flight path within the coverage of referenced NAVAIDS or within the limits of the capability of self-contained systems, or a combination of these capabilities.

All FMSs are capable of performing RNAV operations. Regarding navigation accuracy, these FMSs differ only by demonstrated RNP capabilities and the ability to use GPS updating.

RNP and ANP Definitions

This title is retained for future capabilities.

Basic RNP Concept

This title is retained for future capabilities.

Radius-to-Fix (RF) Legs

Note: Radius-to-Fix (RF) Legs, currently not applicable to MD-88/90.

RF legs are waypoints connected by a constant radius course similar to a DME arc. These are shown on terminal procedures as a curved track between two or more waypoints.

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Autoflight Guidelines

Automatic Flight

Autoflight systems can enhance operational capability, improve safety, and reduce workload. Automatic approach and landing, Category III operations, and fuel-efficient flight profiles are examples of some of the enhanced operational capabilities provided by autoflight systems. Maximum and minimum speed protection are among the features that can improve safety while using NAV, and VNAV. Varied levels of automation are available. The pilot decides what level of automation to use to achieve these goals by selecting the level that provides the best increase in safety and reduced workload.

Automatic systems give excellent results in the vast majority of situations. Deviations from expected performance are normally due to an incomplete understanding by the flight crew. When the automatic systems do not perform as expected, the pilot should reduce the level of automation until proper control of path and performance is achieved. For example, if the pilot failed to select the exit holding feature when cleared for the approach, the aircraft will turn outbound in the holding pattern instead of initiating the approach. At this point, the pilot may select HEADING SELECT and continue the approach while using other automated features. A second example, if the aircraft levels off unexpectedly during climb or descent with VNAV engaged, continue the climb or descent using the MCP in the VERT SPD or IAS mode until the FMS can be programmed.

Early intervention prevents unsatisfactory aircraft performance or a degraded flight path. Reducing the level of automation as far as manual flight may be necessary to ensure proper control of the aircraft is maintained. The pilot should attempt to restore higher levels of automation only after aircraft control is assured. For example, if an immediate level-off in climb or descent is required, it may not be possible to comply quickly enough using the AFDS. The PF should disengage the autopilot and level off the aircraft manually at the desired altitude. After level off, set the desired altitude in the MCP, select an appropriate pitch mode, and re-engage the autopilot.

Recommended Pitch and Roll Modes

If the LEGS page and map display reflect the proper sequence and altitudes, the use of NAV and VNAV is recommended. If NAV is not used, use an appropriate roll mode. In the few instances when VNAV is not used, the following modes are recommended.

IAS is the preferred technique for altitude changes of over 2,000 feet. V/S is preferred if the altitude change is 2,000 feet or less.

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Monitor the FMA closely at approximately 1,000 feet prior to the desired level off altitude to ensure the autopilot captures the altitude. Adjusting the pitch wheel near level off, may result in disengaging the altitude capture mode and the autopilot failing to level the aircraft at the desired altitude. Always verify the FMA progression nearing level off. The FMA will show ALT CAP, ALT HLD, VNAV CAP, or VNAV LVL.

DFGS Guidelines

Crewmembers must coordinate their actions so that the aircraft is operated safely and efficiently.

Autopilot engagement should only be attempted when the aircraft is in trim, F/D commands (if the F/D is on) are essentially satisfied, and the aircraft flight path is under control. The autopilot is not certified or designed to correct a significant out-of-trim condition or to recover the aircraft from an abnormal flight condition and/or unusual attitude.

Autothrottle Use

To simplify thrust setting procedures, autothrottle use is recommended during takeoff and climb in either automatic or manual flight. Make every effort to keep the engines synchronized for passenger comfort. Normally, the ENG SYNC selector is set to N1 for this purpose. If the autothrottle is not used, avoid excessive throttle lever adjustments. Use all engine parameters to maintain balanced thrust.

Manual Flight

The PM should make DFGS mode selections at the request of the PF. Heading and altitude changes from ATC clearances and speed selections associated with flap position changes may be made without specific directions. However, these selections should be announced, such as, “HEADING 170 SET”. The PF must be aware such changes are being made. This enhances overall safety by requiring that both pilots are aware of all selections, while still allowing one pilot to concentrate on flight path control.

Ensure the proper flight director modes are selected for the desired maneuver by referencing the FMA. If the flight director commands are not to be followed, the flight director should be turned off.

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MCP Altitude Setting Techniques Using VNAV

CAUTION: If a descent is being accomplished using IAS or Vertical Speed, all altitude restrictions must be entered in the MCP altitude window until that crossing restriction has been assured. This method greatly increase crew work load and requires increased vigilance.

When using VNAV for published instrument departures and arrivals, the following recommendations should avoid unnecessary level-offs while ensuring altitude constraints are met. Once an altitude clearance has been received and read back the altitude is set in the MCP altitude window, and confirmed. The crew should ensure that VNAV is displayed on the FMA and all intermediate constraint altitudes are displayed on the LEGS page in LARGE FONT.

While climbing with VNAV engaged the aircraft will not climb above an AT or an AT or BELOW constraint. While descending in VNAV the aircraft will not descend below an AT or an AT or ABOVE constraint. In both climb and descent phases, ATC restrictions, aircraft performance, or environmental conditions can result in the aircraft failing to reach the constraint altitude by the waypoint listed. In that case the FMS will warn the crew with an FMS scratchpad message. Pilots must monitor VNAV performance at all times, and respond promptly to FMS messages to ensure compliance with altitude constraints.

Pilots should fully understand the following:

- Published or ATC assigned altitude constraints should be displayed in LARGE FONT on the LEGS page. Altitudes in small font are predictions only.
- The selection of a pitch mode other than VNAV will result in a risk of violating procedure altitude constraints.

If given a clearance to “Descend Via” or “Climb Via”, the lowest/highest altitude on the procedure is set in the MCP altitude window.

Note: For climbs and descents in pitch modes other than VNAV, the MCP altitude must be set at the next altitude constraint.

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MAP Failure

Map failures can occur in any phase of flight.

Complex RVAV arrivals can occasionally exceed the processing limits of the Flight Management Computer (FMC) causing Map failures.

If the Map fails, the following steps will enable the crew to recover the map, continue to the destination, and prevent a re-occurrence.

- Select ARC or ROSE
- Notify ATC; request vectors or direct to a VOR
- Request non-RNAV routing
- Recover MAP using the FMS Map Failure Non-Normal Checklist.

Flight in Moderate to Heavy Rain, Hail, or Sleet

The aircraft is designed to operate satisfactorily when the maximum rates of precipitation expected in service are encountered. However, flight into moderate to heavy rain, hail, or sleet could adversely affect engine operations and should be avoided whenever possible. If moderate to heavy rain, hail, or sleet is encountered, reducing airspeed can reduce overall precipitation intake. Also, maintaining an increased minimum thrust setting can improve engine tolerance to precipitation intake, provide additional stall margin, and reduce the possibility of engine instability or thrust loss.

Turbulent Air Penetration

Severe turbulence should be avoided if at all possible. However, if severe turbulence is encountered, use the Severe Turbulence procedure listed in the Vol. 1, SP.16, Turbulence. Turbulent air penetration speeds provide high/low speed margins in severe turbulent air.

During manual flight, maintain wings level and smoothly control attitude. Use the attitude indicator as the primary instrument. In extreme updrafts or downdrafts, large altitude changes may occur. Do not use sudden or large control inputs. After establishing the trim setting for penetration speed, do not change pitch trim. Allow altitude and airspeed to vary and maintain attitude. However, do not allow the airspeed to decrease and remain below the turbulent air penetration speed because stall/buffet margin is reduced. Maneuver at bank angles below those normally used. Set thrust for penetration speed and avoid large thrust changes. Flap extension in an area of known turbulence should be delayed as long as possible because the aircraft can withstand higher gust loads with the flaps up.

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Normally, no changes to cruise altitude or airspeed are required when encountering moderate turbulence. If operating at cruise thrust limits, it may be difficult to maintain cruise speed. If this occurs, select a higher thrust limit (if available) or descend to a lower altitude.

Ice Crystal Icing

The proper use of engine anti-ice will prevent the effects of ice crystal icing.

Ice crystals at high altitude are often not considered a threat to jet transport airplanes because they don't lead to airframe icing. However, a condition exists where solid ice particles can cool interior engine surfaces through melting and ice buildup can occur. When the ice breaks off, it can result in engine power loss or damage. Symptoms can include surge, flameout, or high vibration.

Typically, the engine power loss has occurred at high altitude, in clouds, as the airplane is flying above an area of convective weather where little or no airplane weather radar returns were observed at the flight altitude. In other cases, flight altitude radar returns were observed and pilots conducted the flight to avoid these areas. Despite pilot avoidance of reflected weather, engine power losses have occurred. Avoidance of ice crystals is a challenge because they are not easily identified.

At temperatures below freezing near convective weather, the airplane can encounter visible moisture made up of high concentrations of small ice crystals. Ice crystals can accumulate aft of the engine fan, in the engine core. Ice shedding can cause engine vibration, engine power loss, and engine damage.

These weather conditions are difficult to detect because ice crystals do not cause significant weather radar returns. They are often found in high concentrations above and near regions of heavy precipitation. Ice crystals do not stick to cold aircraft surfaces.

Flight in clouds containing ice crystals has been associated with engine vibration, engine power-loss, and airplane Total Air Temperature (TAT) probe icing.

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Recognizing Ice Crystal Icing Weather

Ice crystals are most frequently found in areas of visible moisture and above altitudes normally associated with icing conditions. Their presence can be indicated by one or more of the following:

- appearance of rain on the windshield at temperatures too cold for liquid water to exist. This is due to ice crystals melting on the heated windows (sounds different than rain).
- airplane TAT indication remains near 0° C due to TAT probe icing
- areas of light to moderate turbulence
- In IMC with:
  - no significant radar returns at airplane altitude and
  - heavy precipitation below the airplane, identified by amber and red radar returns on weather radar
- cloud tops above typical cruise levels (above the tropopause)

Note: There is no significant airframe icing.

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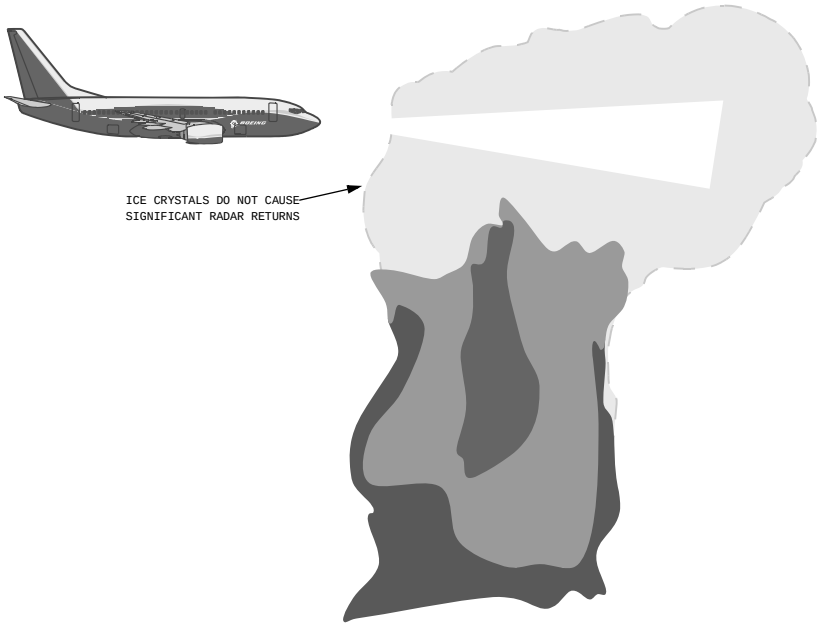
Avoiding Ice Crystal Icing Weather

During flight in IMC, avoid flying directly over significant amber or red radar returns, even if there are no returns at airplane altitude.

Use the weather radar controls to assess weather radar reflectivity below the airplane flight path. Refer to weather radar operating instructions for additional information.



Suspected Ice Crystal Icing

Exit the ice crystal icing conditions. Request a route change to minimize the time above red and amber radar returns.

Wing Anti-Ice Operation - In Flight

The wing anti-ice system may be used for anti-icing in flight. Use WING ANTI-ICE when icing is possible.

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Ground Operations — Chapter 2
Table of Contents — Section TOC

Preflight 2.1
Interior Inspection 2.1
Preflight Procedure 2.1

Pushback and Towing 2.1

Engine Start. 2.2
Normal. 2.2
Anomalies 2.2

Taxi 2.2
Taxi General 2.2
Using Runways as Taxiways. 2.4
Thrust Use 2.4
Thrust Vector Diagrams 2.6
Single Engine Taxi 2.10
Taxi Speed and Braking 2.10
Nose Wheel/Rudder Pedal Steering 2.12
Flight Deck Perspective. 2.13
Turning Radius and Gear Tracking 2.15
Visual Cues and Techniques for Turning while Taxiing 2.17
Sharp Turns to a Narrow Taxiway 2.22
Taxi - Adverse Weather 2.23

Ground De/Anti-Icing 2.24
Definitions and Concepts 2.24
Delta De/Anti-icing Program 2.28
Aircraft or Ground Emergency Communications 2.31
De/Anti-icing Fluids 2.32
Forced Air Deicing 2.34

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Engine Running De/Anti-Icing 2.34
De/Anti-icing Checks 2.35
Communication Procedures 2.37
Holdover Times 2.38
Configuring the Aircraft for De/Anti-icing 2.42

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Preflight
Interior Inspection

Note: If the engines have been shut down for more than 30 minutes, oil quantity may indicate less than full.

Note: Load shedding of the forward galley on the captain's side (G7), will occur if aircraft electrical power is supplied by a single generator. (One engine driven generator, APU only, or external power only.)

Preflight Procedure

To reference the engine out acceleration height during takeoff, the pilot may set the altitude reference index (Baro bug) to 1000 feet AFE or the altitude stated in the company pages.

Note: For a full alignment, IRS mode selectors must be selected to OFF and all IRU advisory lights must be extinguished prior to selecting NAV.

Pushback and Towing

Pushback and towing present serious hazards to ground personnel. Many accidents have occurred where personnel were run over by the aircraft wheels. Good communication between the flight deck and ground personnel is essential for a safe operation.

Pushback and towing involve three phases:

- positioning and connecting the tug and tow bar,
- moving the aircraft, and
- disconnecting the tow bar.

The marshaller, who is walking in the vicinity of the nose wheels, is usually the person injured or killed in the majority of the accidents.

Note: Pushback or tow out is accomplished with the nose wheel steering bypassed.

Note: The aircraft should not be taxied away from a gate, or pushback position, unless the marshaller indicates the aircraft is clear to taxi.

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Engine Start

Normal

Approximate Idle Indications

For approximate idle indications refer to Vol. 1, NP.20, Engine Start procedure.

Normal Engine Start Considerations

- Advancing engine fuel lever to idle prematurely can cause a hot start.
- Keep hand on the fuel lever while observing RPM, EGT, and fuel flow until stabilized.
- If fuel is shutoff inadvertently (by closing fuel lever) do not reselect the fuel lever to idle in an attempt to restart engine.

Anomalies

(88) Consider using the right engine to taxi into position onto the runway. Normal taxi power should accelerate the engine to above 65% N2, ensuring the surge valve is closed and both engines spool up symmetrically.

Taxi

Taxi General

Note: Slow speed taxi over an arresting cable prior to takeoff or after landing is considered acceptable. However, the nosewheel must be inspected at the next aircraft block-in. If required, accomplish the Operating Over a Raised Arresting Cable procedure in Vol. 1, SP.14.

Loss of situational awareness and not following ATC instructions may result in runway incursions. The threat of incursions and collisions is a persistent problem. Planning, active monitoring/crosschecking, and vigilance help prevent ground incidents. If unsure of ATC instructions or obstruction clearance, stop the aircraft.

Use lights in accordance with Vol. 1, NP.12, Lights Usage.

The following guidelines are intended to enhance situational awareness and safety during ground operations:

Prior to Taxi

- Review NOTAMS and current ATIS for any taxiway or runway closures, construction activity, or other airport risks that could affect the taxi route.
- Both pilots verify that the correct aircraft position is in the FMS.
- Brief applicable items from airport diagrams and related charts to include the location of hold short lines and hot spots.
- Ensure both crewmembers understand the expected taxi route.

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- Complex taxi clearances should be written down or entered into the MCDU scratchpad when received.
- An airport diagram should be readily available to each crewmember during taxi.
- Be aware that hold short lines may be located as far as 400 feet from a runway edge.

During Taxi

- Exercise increased awareness when taxiing between parallel runways.
- Reference the heading indicator to assure turns are being made in the correct direction and you are following the assigned taxi route.
- Approaching a clearance limit, verbalize the hold short clearance limit.
- Keep other crewmembers in the loop by announcing when going heads down, and report when back up.
- Progressively follow taxi position on the airport diagram.
- During low visibility conditions, call out all pertinent signs to verify position.
- If unfamiliar with the airport consider requesting a FOLLOW ME vehicle or progressive taxi instructions.
- Use standard radio phraseology.
- Read back all clearances. If any crewmember is in doubt regarding the clearance, verify taxi routing with the assigned clearance or request clarification. Stop the aircraft if the clearance is in doubt.
- If ground/obstruction clearance is in doubt, stop the aircraft and verify clearance or obtain a wing-walker.
- Avoid distractions during critical taxi phases; plan ahead for checklist accomplishment and company communications.
- Consider delaying checklist accomplishment until stopped during low visibility operations.
- Do not allow ATC or anyone else to rush you.
- Be constantly aware of the equipment, structures, and aircraft behind you when the engines are above idle thrust.

Prior to Takeoff

- If you have been holding in position on the runway for more than 90 seconds, or upon seeing a potential conflict, contact the tower.
- When assigned a departure at an intersection, state the intersection departure during the clearance and read back.

If extended taxi time will result in fuel below min fuel for takeoff:

- Contact Dispatch to coordinate and adjust designation of some Required Additional Fuel to Discretionary Additional Fuel. This lowers the Minimum Fuel for Takeoff (desirable).
- Return to the gate (last resort).

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At the runway if you are overweight for any reason (e.g., did not burn sufficient taxi fuel):

- use a lower assumed temperature setting to increase performance,
- TOPR the runway with the current winds,
- delay takeoff until fuel has been burned, or
- request a TOPR/WDR update via ACARS.

Runway Safety

- Verify the runway is clear (both directions) and clearance is received prior to entering a runway.
- Confirm aircraft location utilizing an outside source such as runway signage, painted runway number markings, and/or aircraft heading.

Prior to Landing

- Plan/brief the expected taxiway exit and route to parking.

After Landing

- Ensure taxi instructions are clearly understood, especially when crossing closely spaced parallel runways.
- Delay non-essential radio or cabin communications until clear of all runways.
- Wait until you have exited the runway and you are sure of your taxi clearance prior to beginning an after landing checklist, or non-essential communications.

Using Runways as Taxiways

- Minimize distractions, such as heads down time, discretionary company and cabin communications, engine starts, and checklists when on any runway.
- Runways are typically wider than taxiways. As a result of field of vision, signs located at the edge of a runway may be more difficult for the pilot to see and identify than on the edge of a taxiway.
- While taxiing on a runway that crosses an active runway, the runway intersections points are frequently missing signs, markings, and lighting typically found on a taxiway.

Thrust Use

Thrust use during ground operation demands sound judgment and technique. Even at relatively low thrust the air blast effects from the large, high bypass engines can be destructive and cause injury. Aircraft response to throttle movement is slow, particularly at high gross weights. Engine noise level in the flight deck is low and not indicative of thrust output.

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In some cases simply releasing the brakes is sufficient to begin moving, while other conditions will require greater thrust. Allow time for engine spool-up and aircraft movement before increasing thrust further. If more than 75% N2 is necessary, ensure area behind aircraft is clear or consider starting the other engine.

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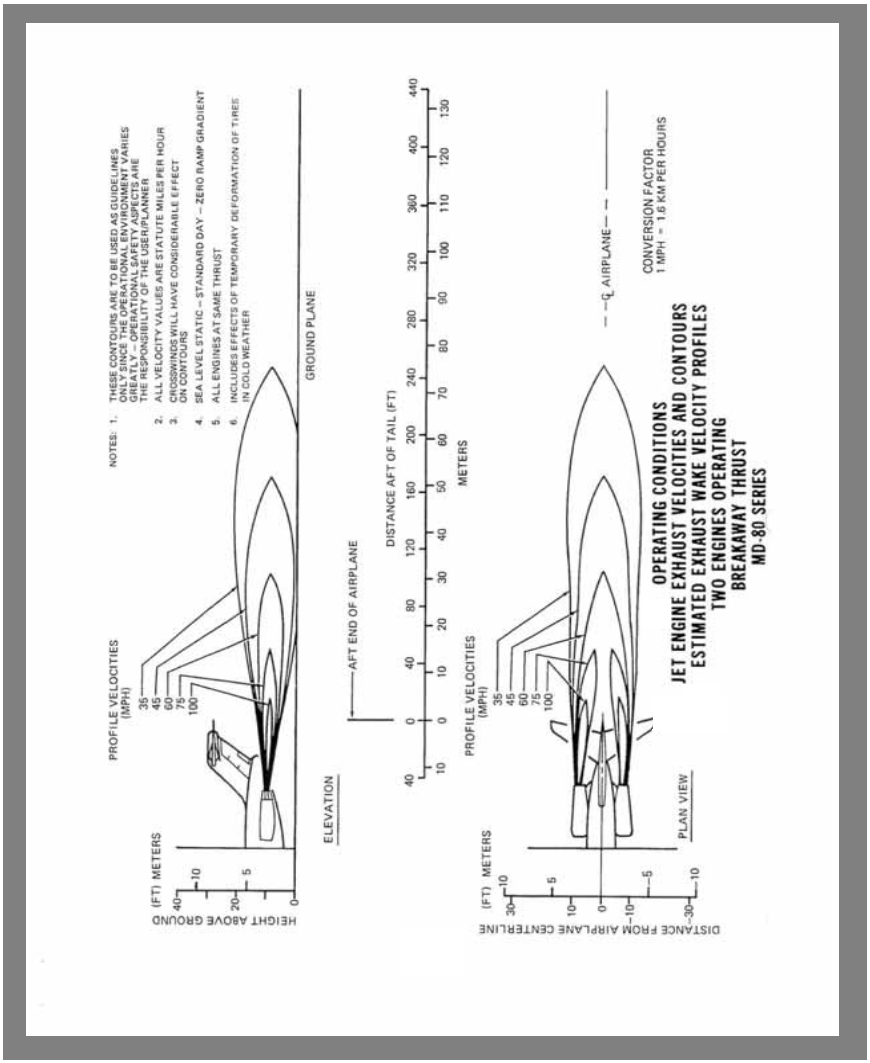
Thrust Vector Diagrams

MD-88 Thrust Vector - Breakaway Power



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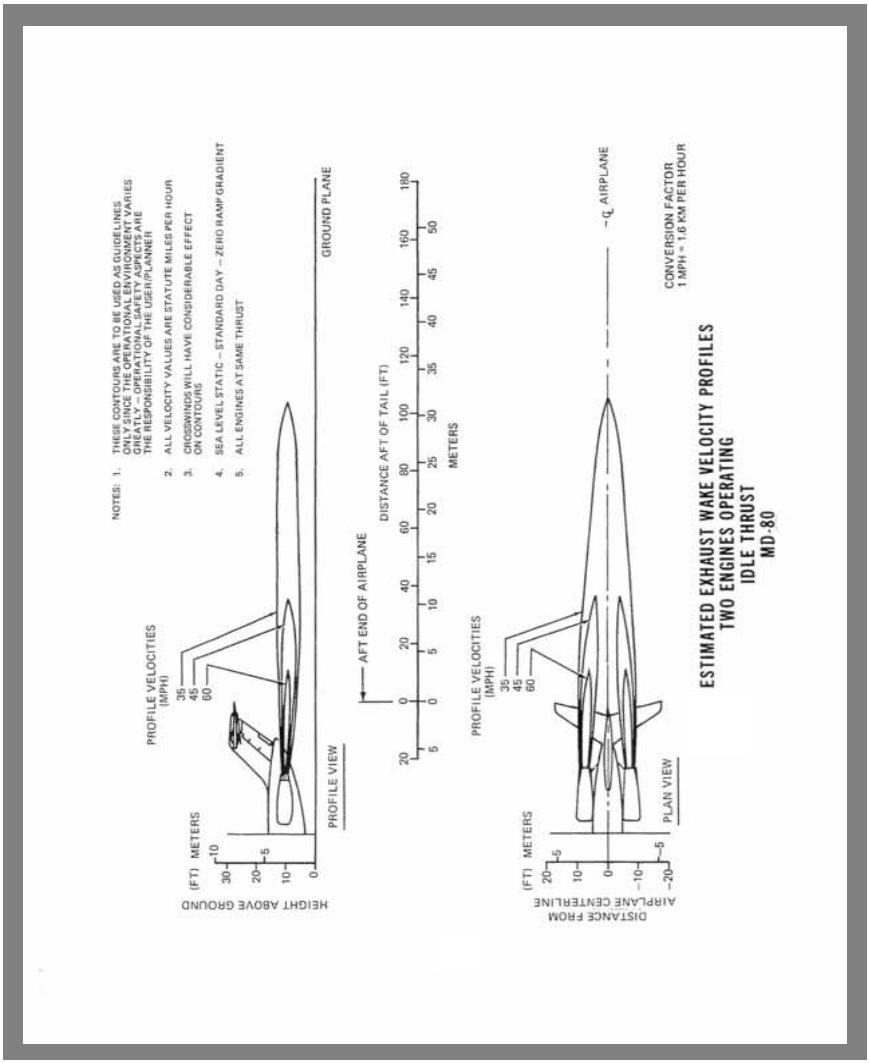
MD-88 Thrust Vector - Idle Power



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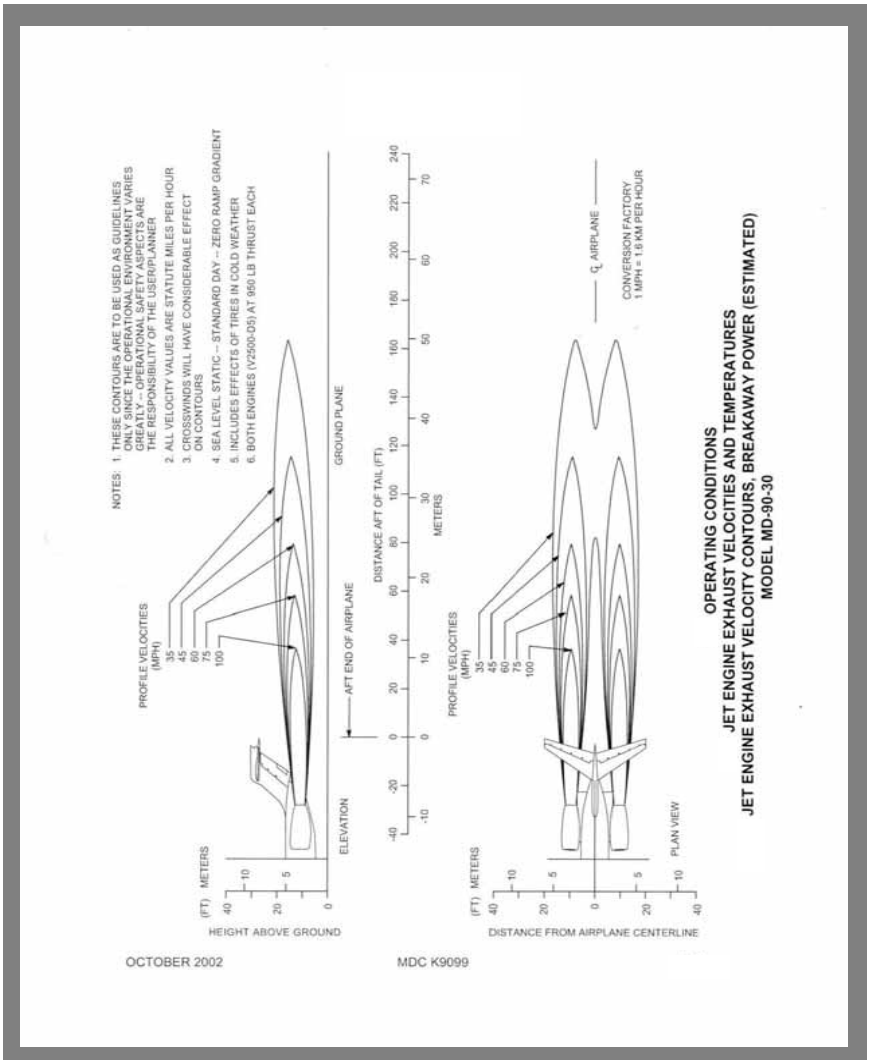
MD-90 Thrust Vector - Breakaway Power



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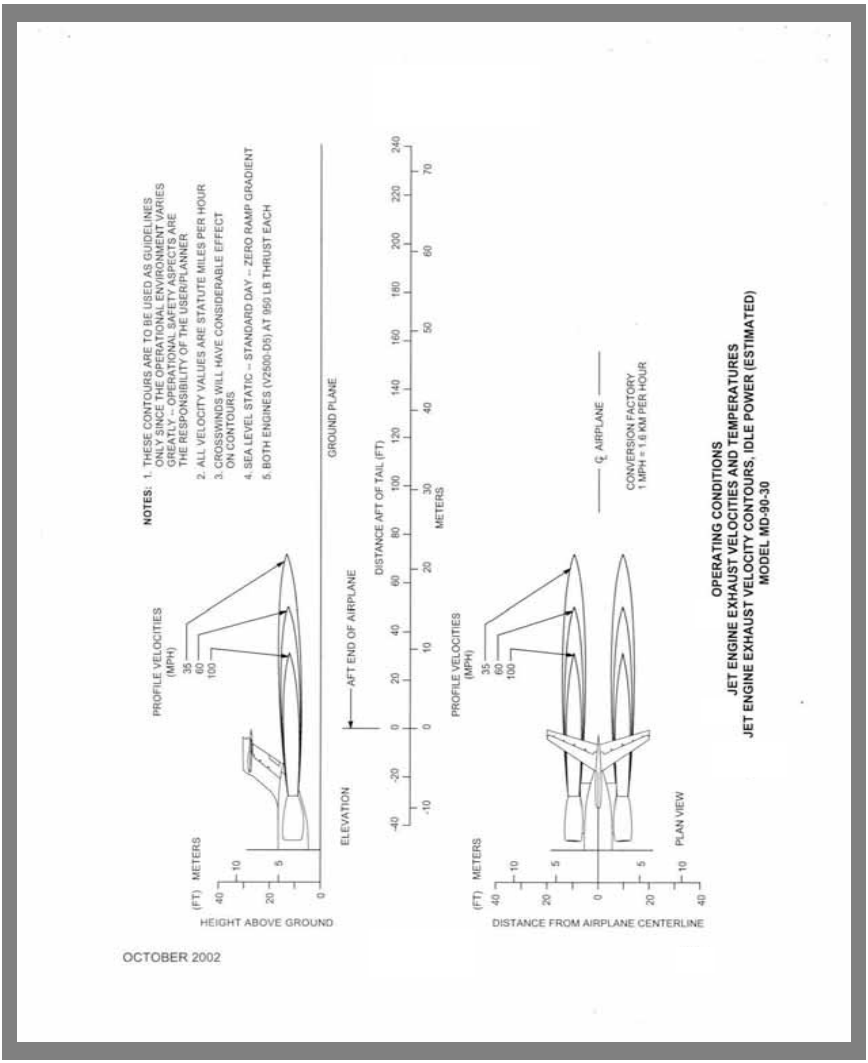
MD-90 Thrust Vector - Idle Power



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Single Engine Taxi

High bypass engines require warm up prior to applying takeoff thrust and cool down prior to shutting down. (90) If the engine has been shut down for several hours, it is desirable to operate the engine at as low a thrust setting as practical for several minutes prior to takeoff.

If taxiing with an engine shut down, the crew must be aware of systems requirements; i.e., hydraulics, brakes, electrical, particularly any degraded system operation due to enroute failures. When making a minimum radius turn, consider turning in a direction that puts the operating engine on the outside of the turn. In operational environments such as uphill slopes, soft asphalt, high gross weights, congested ramp areas, high density altitude airports, and wet/slippery ramps and taxiways; consider taxiing with both engines operating. APU fuel consumption (approximately 175 PPH) is not included in the fuel displayed. The FMS will not calculate fuel consumption during single engine taxi (both fuel levers must be on).

Note: If required to augment pneumatic pressure, optimum cooling is achieved by leaving the crossfeeds OPEN with APU AIR switch in the ON position. Close left crossfeed prior to starting the second engine. Do not use the AIR COND COLDER position with engine(s) running.

Taxi Speed and Braking

88

CAUTION: Due to brake chatter, which is inherent to the design of 88 brakes, plan braking requirements well in advance of intended stopping point.

To begin taxi, release brakes, smoothly increase thrust to minimum required for the aircraft to roll forward, and then reduce thrust as required to maintain normal taxi speed. A turn should normally not be started until sufficient forward speed has been attained to carry the aircraft through the turn at idle thrust.

The aircraft may appear to be moving slower than it actually is due to the flight deck height above the ground. Consequently, the tendency may be to taxi faster than desired. This is especially true during runway turnoff after landing. The ground speed display on the flight instruments may be used to determine actual taxi speed. The appropriate taxi speed depends on turn radius and surface condition.

Note: Some taxi speeds, usually between 10 and 20 knots, can cause an increase in aircraft vibration, especially on rough taxiways. If this occurs, a slight increase or decrease in speed reduces or eliminates the vibration and increases passenger comfort.

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Taxi speed should be closely monitored during taxi out, particularly when the active runway is some distance from the departure gate. Normal taxi speed is approximately 20 knots, adjusted for conditions. On long straight taxi routes, speeds up to 30 knots are acceptable, however at speeds greater than 20 knots use caution when using the nose wheel steering wheel to avoid overcontrolling the nose wheels. When approaching a turn, speed should be slowed to an appropriate speed for conditions. On a dry surface, use approximately 10 knots for turn angles greater than those typically required for high speed runway turnoffs.

Under normal conditions, differential braking and braking while turning should be avoided. Allow for decreased braking effectiveness on slippery surfaces.

Avoid following other aircraft too closely. Jet blast is a major cause of foreign object damage.

During taxi, the momentary use of idle reverse thrust may be needed on slippery surfaces for aircraft control. Use caution as spoilers will deploy and autobrakes will apply if armed. The use of reverse thrust above reverse idle is not recommended due to the possibility of foreign object damage and engine surge. Consider having the aircraft towed rather than relying on the extended use of reverse thrust for aircraft control.

Note: High taxi speed combined with heavy gross weight and a long taxi distance can result in tire sidewall overheating.

Note: Taxiing long distances with continuous light brake pressure can cause the wheel fuse plugs to melt and deflate the tires.

These braking technique recommendations are intended as general taxi guidelines only. Safety and passenger comfort should remain the primary considerations.

Carbon Brakes

90

Carbon brake wear is primarily dependent on the total number of brake applications. One firm brake application causes less wear than several light applications. Maximum carbon brake life can be achieved during taxi by using a small number of long, moderately firm brake applications instead of numerous light brake applications. This can be achieved by allowing taxi speed to increase from below desired speed to above target speed. Then use a single moderately firm brake application to reduce speed below that desired and repeat as necessary. Carbon brake wear is much less sensitive to aircraft weight and speed than steel brake wear.

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Steel Brake Differences

88

When the airplane is equipped with steel brakes, avoid prolonged brake application to control taxi speed as this causes high brake temperatures and increased wear of brakes. Steel brake wear is directly proportional to the kinetic energy absorbed by the brakes. Maximum steel brake life can be achieved during taxi by using a large number of small, light brake applications, allowing some time for brake cooling between applications. High airplane gross weights and high brake application speeds tend to reduce steel brake life because they require the brakes to absorb a large amount of kinetic energy.

Nose Wheel/Rudder Pedal Steering

The captain's position is equipped with a nose wheel steering wheel. The nose wheel steering wheel is used to turn the nose wheels through the full range of travel at low taxi speeds. Maintain positive pressure on the nose wheel steering wheel at all times during a turn to prevent the nose wheels from abruptly returning to center. Rudder pedal steering turns the nose wheels through a limited range of travel. Straight ahead steering and large radius turns may be accomplished with rudder pedal steering. On straight taxiways, the aircraft is correctly aligned on the centerline when the centerline is lined up with the captain's right heel with the right rudder pedal.

If nose wheel "scrubbing" occurs while turning, reduce steering angle and/or taxi speed. Avoid stopping the aircraft in a turn as excessive thrust is required to start taxiing again.

Differential thrust may be required at high weights during tight turns. This should only be used as required to maintain the desired speed in the turn. After completing a turn, center the nose wheels and allow the aircraft to roll straight ahead. This relieves stresses in the main and nose gear structure prior to stopping.

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Flight Deck Perspective

There is a large area near the aircraft where personnel, obstacles, or guidelines on the ground cannot be seen, particularly in the oblique view across the flight deck. Special care must be exercised in the parking area and while taxiing. When parked, the pilot should rely on ground crew communications to a greater extent to ensure a safe, coordinated operation.

The pilot's seat should be adjusted for optimum eye position. The rudder pedals should be adjusted so that it is possible to apply maximum braking with full rudder deflection.

During taxiing, the pilot's heels should be on the floor, sliding the feet up on the rudder pedals only when required to apply brakes to slow the taxi speed, or when maneuvering in close quarters on the parking ramp.

Flight Deck References During Straight-Line Taxi

Certain flight deck references can be utilized to indicate the track of the main landing gear and wing tips while taxiing in a straight line.

These references are general guidelines only and crews must not rely solely on these to assure wing tip and/or main gear clearance. If ever in doubt to wing tip and/or main gear clearance, stop the aircraft and get wing walkers or have the aircraft towed.

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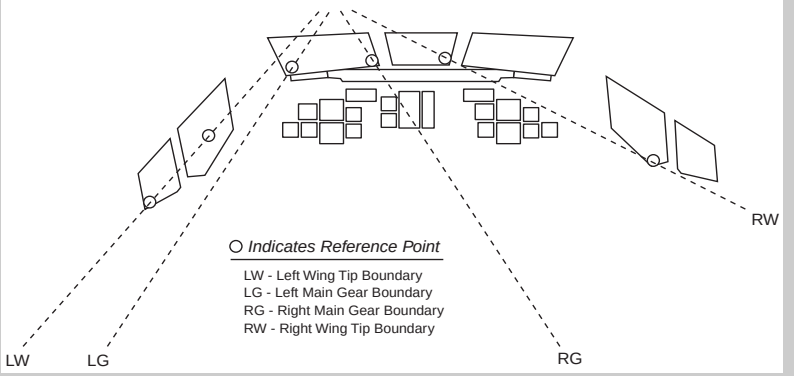
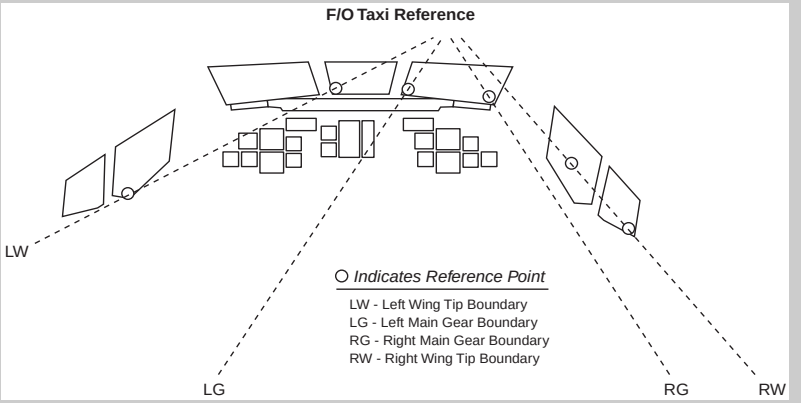
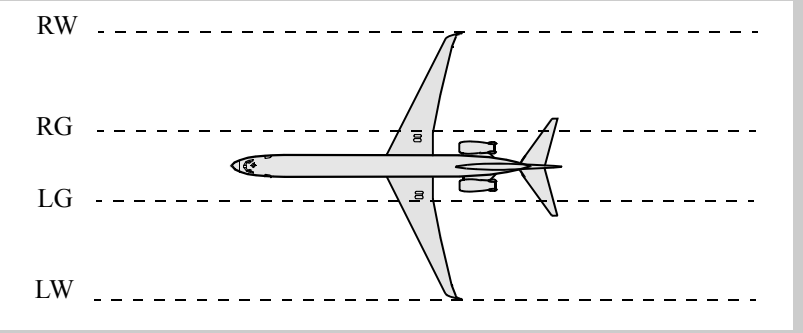
Captain Taxi Reference



F/O Taxi Reference





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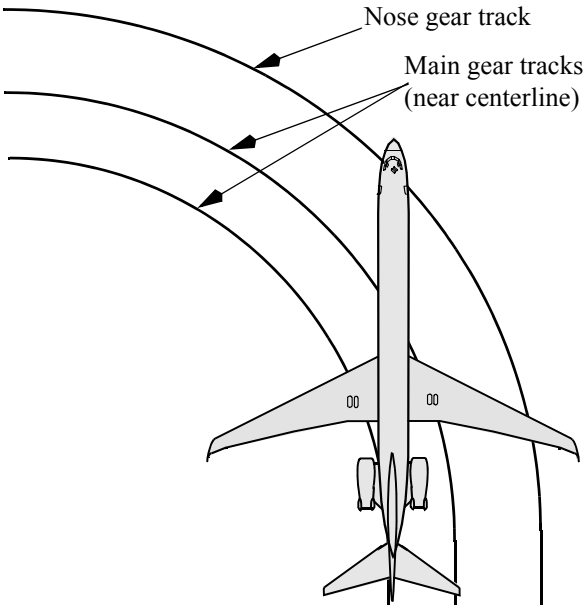
Turning Radius and Gear Tracking

During all turning maneuvers, crews should be aware of their position relative to the nose and main landing gear. The pilot seat position is indicated in the tables in this chapter.

As the following diagram illustrates, while the aircraft is turning, the main gear tracks inside the nose gear. The smaller the radius of the turn, the greater the distance that the main gear tracks inside the nose gear and the greater the need to steer the nose gear outside of the taxi path (oversteer).



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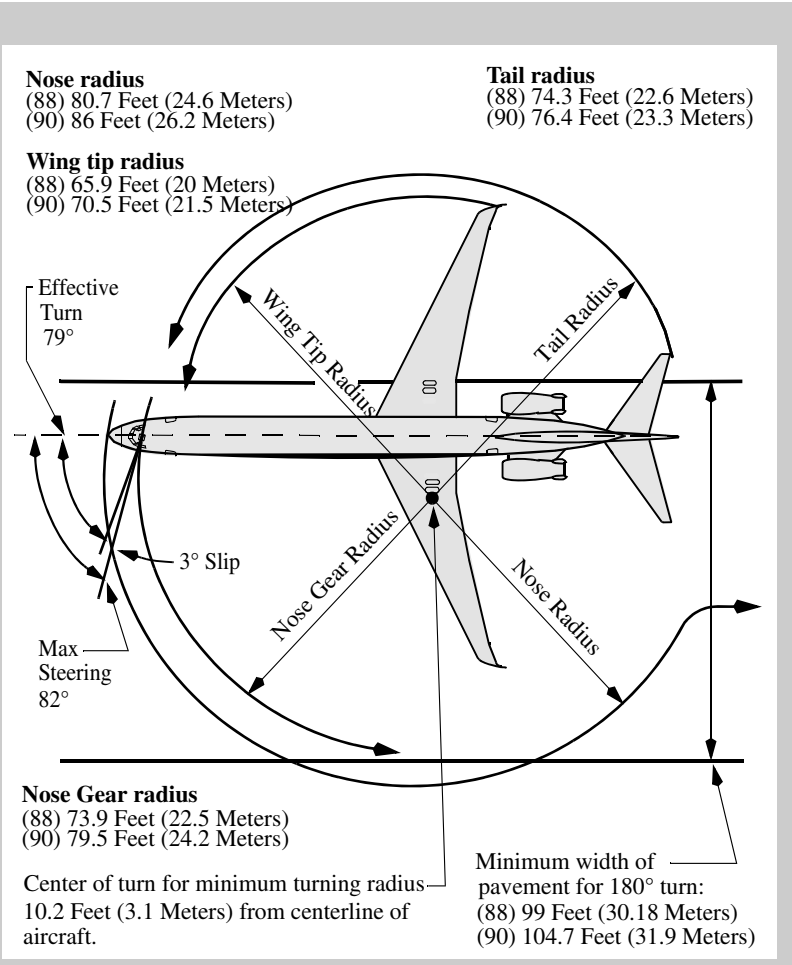
Turning Radius Diagrams

The following illustration shows the minimum turn radius capability. The nose swings the largest arc while turning and determines the minimum obstruction clearance path. All other portions of the aircraft are within this arc. The tail swings a larger arc than the wing tip, therefore, wing tip clearance does not guarantee tail clearance.



Note: While both the MD-88 and MD-90 are capable turning 180° on smaller pavement widths, do not attempt a 180° turn on a pavement dimension less than 125 feet.

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Visual Cues and Techniques for Turning while Taxiing

The following visual cues assume the pilot's seat is adjusted for proper eye position. The following techniques also assume a typical taxiway width (75 feet). Since there are many combinations of turn angles, taxiway widths, fillet sizes and taxiway surface conditions, pilot judgment must dictate the point of turn initiation and the amount of nose gear steering wheel required for each turn. The Captain and First Officer must work as a team to ensure proper obstacle clearance. Except for turns less than approximately 30°, speed should be 10 knots or less prior to turn entry. The nose wheel is located directly underneath the throttles. For all turns, keep in mind the main gear are located well behind the nose wheels, causing them to track inside the nose wheels during turns. The pilot position forward of the main gear for each airplane is depicted in the table below.

Model	Pilot Seat Position (forward of main gear feet (meters))
MD-88	72.4. (22)
MD-90	77.2 (23.5)

Turns less than 90°

During the turn, steer the nose wheels far enough beyond the centerline of the turn to keep the main gear close to the centerline.

Turns of 90° or more

Initiate the turn after overshooting the intersecting taxiway centerline (or intended exit point) and the nose gear is approaching the edge of the taxiway. Initially use approximately full nose gear steering wheel displacement. Adjust the handwheel input as the aircraft turns to keep the nose wheels outside of the taxiway centerline, near the outside radius of the turn. Nearing turn completion, when the main gear are clear of the inside radius, gradually release the nose gear steering wheel input as the aircraft lines up with the intersecting taxiway centerline or intended taxi path.

Turns of 180°

If the available taxi surface is narrow, coordination with external observers may be required to complete the operation safely. Reference special airport operating instructions, if available. In some cases (e.g., heavy weight, pilot uncertainty of runway and/or taxiway pavement edge locations and related safety margins, nearby construction, vehicles, potential FOD damage), towing the aircraft to the desired location may be the safest option.

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If a minimum radius 180° turn is necessary, consider using the ground crew to monitor the wheel path and provide relevant information as the turn progresses. The ground crew should be warned of the risk associated with jet blast and position themselves to avoid the hazard. Also ensure that obstacle clearance requirements are met. Since more than idle thrust is required, the flight crew must be aware of buildings or other objects in the area being swept by jet blast during the turn.

Note: Monitor the nose gear track closely, because it leaves the pavement in the turn before the main gear.

Approach the edge of the taxi surface at a shallow angle until the outboard side of the main gear wheels are near the edge.

Note: Painted runway markings are slippery when wet and may cause skidding of the nose gear during the turn.

Turning radius can be reduced by following a few specific taxi techniques. Taxi the aircraft so that the main gear tires are close to the runway edge. This provides more runway surface to make the turn. Stop the aircraft completely with the thrust at idle. Hold the nose wheel steering wheel to the maximum steering angle, release the brakes, then add thrust on the outboard engine. Only use the engine on the outboard side of the turn and maintain 5 to 10 knots during the turn to minimize turn radius. Light intermittent braking on the inside main gear helps decrease turn radius. Stopping the aircraft in a turn is not recommended unless required to reduce the turn radius. As the aircraft passes through 90° of turn, steer to place the main gear approximately on the runway centerline, then gradually reduce the nose wheel steering wheel input as required to align the aircraft with the new direction of taxi.

This technique results in a low speed turn and less runway being used. It does not impose undue stress on the landing gear and tires provided the wheel brakes are not locked during the turn. If the nose gear skids, a good technique is to apply the inside wheel brake briefly and keep the aircraft turning with asymmetric thrust as needed. If the turnaround is planned on a surface significantly greater in width than the minimum required, a turn entry could be made, without stopping, at 5-10 knots speed, using intermittent inside wheel braking and thrust as needed. Wind, slope, runway or taxiway surface conditions, and center of gravity may also affect the turning radius.

The following diagrams show suggested aircraft ground tracks for minimum radius 180° turns with various runway turnaround configurations. These ground tracks provide the best maneuver capability while providing the maximum runway length available for takeoff at the completion of the turn. However, this type of maneuvering is normally not required unless operating on runways less than 148 feet (45m) in width.

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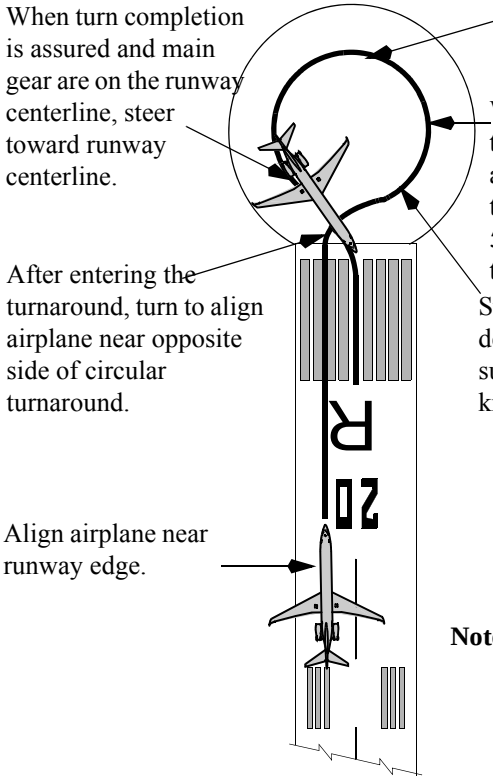
Techniques when using a Circular Turnaround



Note: Follow turnaround steering guidance cues if available.

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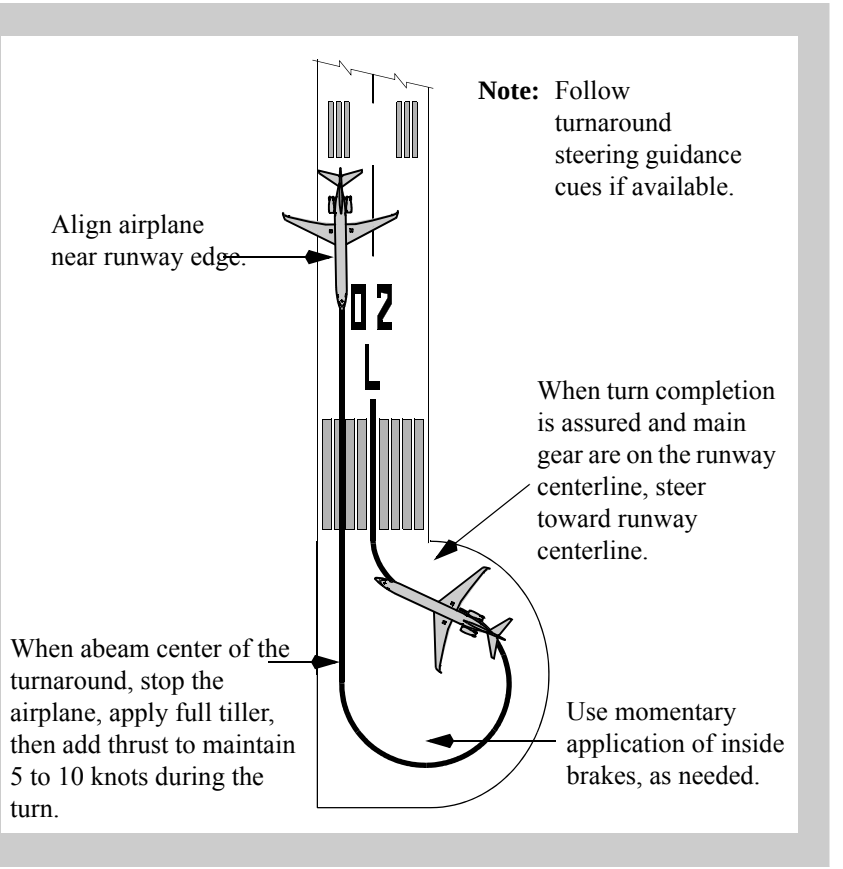
Techniques when using a Hammerhead Turnaround



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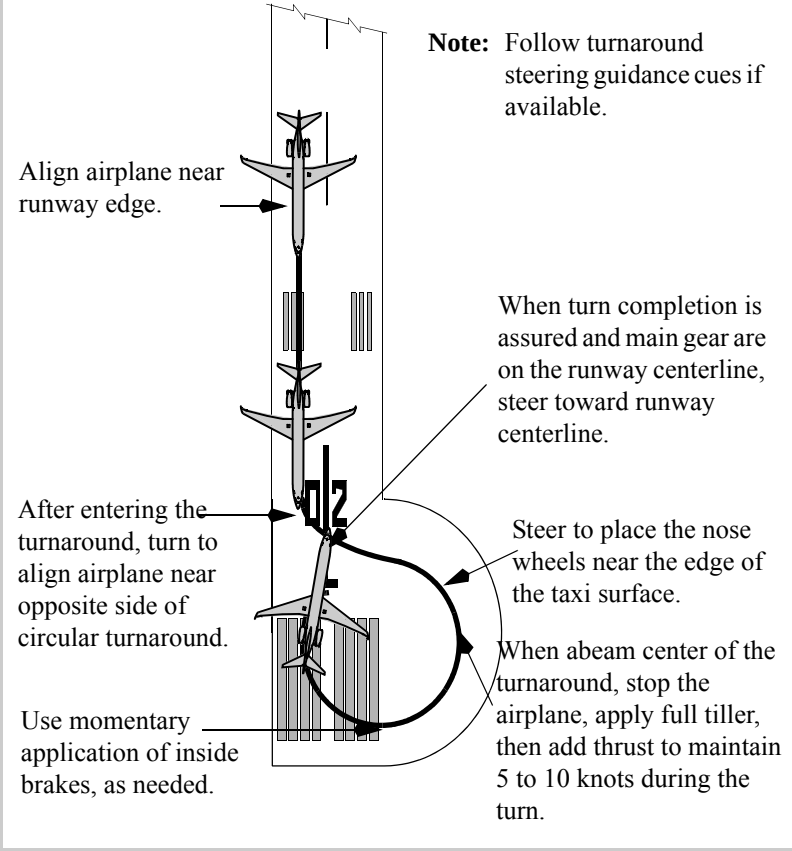
Techniques when using a Hammerhead Turnaround



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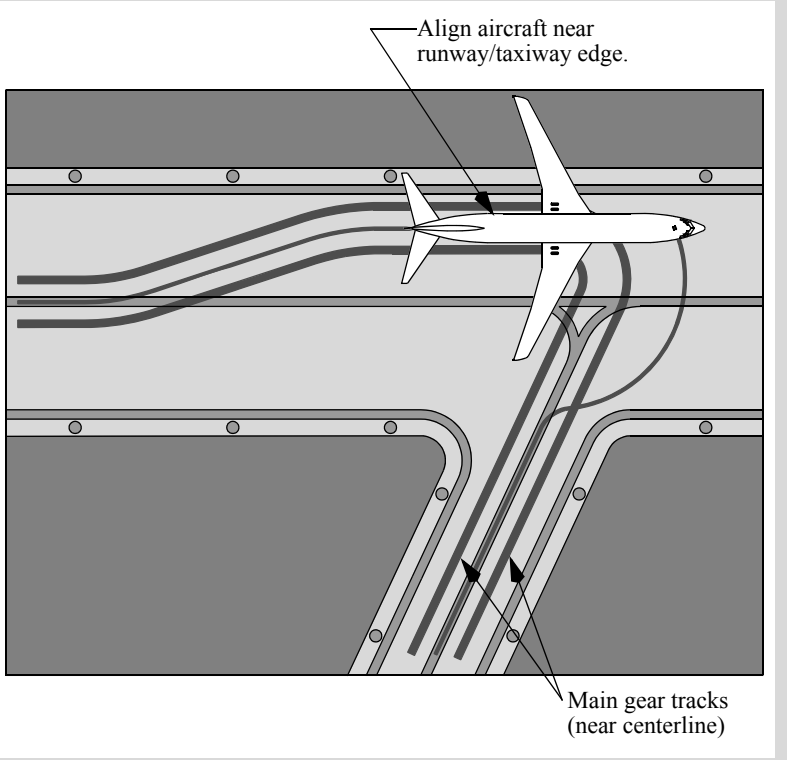
Sharp Turns to a Narrow Taxiway

When making a sharp turn from a runway or a wide taxiway to a very narrow taxiway, consider displacing the aircraft to the far side of the runway or taxiway before initiating the turn. This allows more room for the inboard gear to stay on the taxi surface during the turn, and ensures a more accurate centerline alignment entering the narrow taxiway.

Note: Be aware of wing clearance during the turn.



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Taxi - Adverse Weather

Taxi under adverse weather conditions requires more awareness of surface conditions.

When taxiing on a slippery or contaminated surface, particularly with strong crosswinds, use reduced speeds. Use of differential engine thrust assists in maintaining aircraft momentum through the turn. When nearing turn completion, placing both engines to idle thrust reduces the potential for nose gear skidding. Avoid using large nose wheel steering inputs to correct for skidding. Differential braking may be more effective than nose wheel steering on slippery or contaminated surfaces. If speed is excessive, reduce speed prior to initiating a turn. If no reaction to the nose gear steering wheel occurs while taxiing on a slippery surface, the nose wheel is skidding. Center the nose wheel to prevent nose gear damage that could occur if surface traction is regained.

Note: A slippery surface is any surface where the braking capability is less than that on a dry surface. Therefore, a surface is considered “slippery” when it is wet or contaminated with ice, standing water, slush, snow, or any other deposit that results in reduced braking capability.

Low Visibility

Pilots need a working knowledge of airport surface lighting, markings, and signs for low visibility taxi operations. Understanding the functions and procedures to be used with stop bar lights, ILS critical area markings, holding points, and low visibility taxi routes is essential to conducting safe operations. Many airports have special procedures for low visibility operations. For example, airports operating under FAA criteria with takeoff and landing minimums below 1200 feet (350 meters) RVR are required to have a low visibility taxi plan.

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Ground De/Anti-Icing

Definitions and Concepts

Ground de/anti-icing background information and policies are described in this section and the De/Anti-Icing Guide. Procedures for aircraft specific de/anti-icing are located in Vol. 1, SP.16.

Deicing

Deicing is the procedure of removing frost, ice, slush, or snow from the aircraft in order to provide clean surfaces. On the ground this may be accomplished by:

- Using any mechanical or pneumatic means that will not damage the aircraft.
- Using heated deicing fluid to remove all forms of frozen contamination (including environmental frost). Heated fluids penetrate the frozen contaminants and contact the aircraft skin. The high thermal conductivity of the aircraft skin causes the heat to spread, breaking the bond of the ice and snow, causing it to melt or fall off the aircraft.

Anti-icing

Anti-icing is a precautionary procedure that provides protection against the formation of frost or ice, and accumulation of snow or slush on treated surfaces of the aircraft for a limited period of time (holdover time). Anti-icing fluid is the only protection against airfoil icing prior to getting airborne. Therefore, fluid application should be completed as close to takeoff time as possible.

Additional Anti-icing

If an aircraft which has been de/anti-iced is delayed on the ground long enough that anti-icing protection is no longer effective, or if for any reason the de/anti-icing process is interrupted while freezing/frozen precipitation is falling, the ground de/anti-icing procedure must be reaccomplished in its entirety.

The contaminated anti-icing fluid and all frozen contamination must be completely removed by deicing before making another application of anti-icing fluid. A new holdover time must be determined after completing additional de/anti-icing.

Clean Aircraft Concept

The airline industry, in concert with the FAA, is operating with a clean aircraft concept to minimize the effects of all forms of frozen contamination on aircraft surfaces.

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Takeoff is prohibited when frost, ice, snow or slush is adhering to the wings, control surfaces, engine inlets, or other critical surfaces of the aircraft.

- Do not rely on air flow during takeoff roll to remove frozen precipitation that may be adhering to the aircraft.
- A coating of frost up to 1/8 inch thick on the lower wing surface, below the fuel tank area, is permissible provided it is caused by cold soaked fuel.
- It is acceptable to have a thin coating of hoar frost on the fuselage, provided all vents and ports are clear. If the hoar frost extends down to the area of the windows, the fuselage must be deiced.

Cold soaked wings

A cold soaked wing condition can occur when an aircraft lands with a large amount of fuel remaining in the wing tanks. During cruise at high altitude, the aircraft is subjected to extremely cold temperatures for an extended period of time causing the aircraft skin and fuel to become super cooled. If enough super cooled fuel is remaining in the wing tanks to contact the upper wing surface, it will maintain the skin at a temperature below freezing. When this happens, any moisture contacting the upper wing surface may form frozen contamination, even in ambient air temperatures as high as 15°C (59°F).

A cold soaked wing should also be suspected if both of the following conditions are met:

- Frost or ice is observed on the wing's underside during the walk around, and
- A large amount of fuel was remaining in the wing tanks after landing.

If cold soaked wings are suspected, cabin windows may be used during the preflight to visually inspect the upper wing surfaces for frost or ice. The quickest way to alleviate a cold soaked wing condition is to add warm fuel to the wing tanks.

Critical Aircraft Surfaces and Components

Critical aircraft surfaces and components are those surfaces which must be clear of adhering frozen contamination before beginning takeoff roll. Critical aircraft surfaces include, but may not be limited to:

- Wings, slats, flaps, ailerons, spoilers
- Horizontal stabilizer and elevator
- Vertical stabilizer and rudder
- Pitot heads, static ports, ram-air intakes, engine and flight instrument probes, other kinds of instrument sensor pickups
- Engine and APU inlets and exhausts
- Radome.

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Representative Aircraft Surfaces

Representative aircraft surfaces are those which the pilot can readily observe to determine whether or not frost, ice, or snow is accumulating or forming on that surface. By using a representative surface, a pilot can make a reasoned judgment regarding whether or not frost, ice, or snow is adhering to other aircraft surfaces.

Representative aircraft surfaces visible from the flight deck are:

- Fuselage
- Radome

Representative aircraft surfaces visible from the best vantage point(s) in the cabin are:

- Wing area upper surfaces
- Wing leading edges
- Engine inlets

Best Vantage Point(s)

The best vantage point is the location in the aircraft where a pilot can best check representative aircraft surfaces. This will normally be a passenger window in the over-wing area. It may be necessary in some circumstances to move a few rows to get the best view of the engines. Outside lighting conditions and glare may also affect which specific location is the best vantage point.

Holdover Time

Holdover time is the estimated time that anti-icing fluid will prevent the formation of frozen contaminants on the treated surfaces of the aircraft. Holdover time is determined by the pilot using the Holdover Time Tables.

Holdover time starts when the final application of fluid begins. The final fluid applied will be either:

- de/anti-icing fluid in the one step procedure, or
- anti-icing fluid in the two step procedure.

Holdover time ends when either:

- the applied fluid loses its effectiveness, or
- the time extracted from the holdover time range expires.

Ground Icing Conditions

Guidance for determining precipitation categories (type) and intensities (light, moderate, and heavy) is located in the Airway Manual, Weather, Hazardous Weather, and the associated Ground Precipitation Intensity chart.

WARNING: Do not take off during heavy freezing drizzle, heavy ice pellets, moderate freezing rain, or heavy freezing rain.

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Operational Effects of Frozen Contamination

Frost, ice, and/or snow adhering to airfoils, engine inlets, flight controls and flight instrument sensors, even in small amounts, can have a critical effect on aircraft performance. For example, ice formations on the wing's leading edges and upper surfaces creating texture roughness of medium to coarse sandpaper can reduce lift as much as 30 percent and increase drag by 40 percent. Therefore, frozen contamination on the aircraft in any form poses a serious threat to flight safety due to degraded operational performance.

Degraded aerodynamic performance such as:

- Lift decreases - Frozen contamination may destroy the lifting ability of an airfoil, including leading edge devices. The aircraft may not lift off at a normal pitch attitude. Required gaps in leading edge devices may be blocked and further reduce lift on one or both wings.
- Drag/weight increases - An aircraft may fail to reach takeoff speed in the calculated distance.
- Stall speed increases - Buffet or stall may occur before activation of stall warning systems.
- Controllability decreases - Caused by changing the aerodynamic properties of the control surface due to ice. For example, ice on the leading edge of the horizontal stabilizer can affect pitch control, especially during rotation.

Reduction in available engine power caused by:

- icing of engine inlets, guide vanes or compressor blades; or
- ingestion of ice shedding from other parts of the aircraft.

Impairment of flight and engine performance indicators resulting in:

- incorrect power settings due to EPR probe icing,
- incorrect airspeed indication caused by pitot/static probe icing, or
- erroneous stall warning caused by ice on the AOA probe.

Degraded flight control response as ice may interfere with the free movement of the flight controls.

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Delta De/Anti-icing Program

Delta Air Lines' Ground De/Anti-icing Program is coordinated among Airport Customer Service, Maintenance, Flight Control, Flight Operations, Fleet Management and Reliability, and Flight Safety. Each Delta deicing station will have designated trained personnel on duty to determine when to initiate ground de/anti-icing operations. At airports where no Delta personnel are permanently assigned, the captain may declare the de/anti-icing program in effect. In this case, the captain shares responsibility for the effectiveness of the effort with the ground crew. The procedures outlined in this section will help guide the captain through this decision making process.

There are several components to Delta's De/Anti-icing Program. Pilots need to be aware of how key components play an integral part in ensuring safe winter flight operations.

De/Anti-icing Alert Plan

A Deicing Alert Chart will be issued daily by Delta Meteorology to the OCC Duty Director. This chart reflects forecasted freezing/frozen precipitation for specific geographic regions for the next day's flying (24 - 48 hours in advance). Affected stations will be notified, and plans will be made to initiate local de/anti-icing operations. Flight Control will work in conjunction with individual stations to determine possible changes to the flight schedule based on any anticipated decrease in airport air traffic capacity.

Station De/Anti-icing Plans

Each Delta station that conducts de/anti-icing operations is required to have a detailed de/anti-icing plan on file. This plan contains, but is not limited to, the following information:

- Persons responsible for implementing/terminating the de/anti-icing plan
- Deicing equipment and fluids
- Location of de/anti-icing areas
- Local procedures including communication with the flight crew and coordination with local ATC.

ATC will be notified whenever the local de/anti-icing plan is in effect. Departure runway queues will be managed by ATC in order to minimize the amount of time an aircraft spends on the ground after being de/anti-iced.

Special procedures for the pilots will be contained in the Airway Manual, company pages, or noted in the Airport Remarks section of the flight plan.

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De/Anti-Icing/Overnight Protection

If the aircraft is de/anti-iced prior to the arrival of the flight crew, a completed Captain Notification And Overnight Protection Form will be left on the captain's seat or with the flight papers. If the aircraft has been de/anti-iced prior to the arrival of the flight crew, the flaps and slats must be inspected prior to departure.

During forecasted overnight icing conditions, Type IV fluid may be applied to the fuselage, wings and tail. A completed Captain Notification And Overnight Protection Form will be left on the captain's seat or with the flight papers.

CAUTION: All Type IV fluid used for overnight protection must be removed with Type I fluid prior to departure.

Responsibility for De/Anti-icing of Aircraft

The captain has the ultimate responsibility for ensuring the aircraft's critical surfaces are free of frozen contamination and the flight can be operated safely. The ground deicing crew shares in this responsibility by providing an aircraft that complies with the clean aircraft concept.

The flight crew will notify station personnel as soon as possible when deicing is required, and coordinate with Ground Operations prior to deicing/anti-icing operations. The Station Manager (or qualified designee) has authority to direct de/anti-icing before the captain arrives at the airplane.

ACS and/or contractors accomplish aircraft de/anti-icing. As always, pilot vigilance is paramount during any de/anti-icing procedure. If possible, the pilots should evaluate the operation from the flight deck as it is being conducted and:

- If deicing or anti-icing is not being performed properly or safety is jeopardized, stop the operation and attempt to have the problem corrected.
- When possible, provide timely feedback on individual station de/anti-icing performance to the Dispatcher. A telephone report is preferred.
- Document all de/anti-icing problems or accolades on an FCR, ASR, or ASAP as appropriate.

Depending on the circumstances and local station procedures, aircraft de/anti-icing may be accomplished:

- Whenever requested by the captain
- During overnight parking (prior to pilots' arrival)
- At the gate - prior to pushback
- After pushback - clear of the gate
- At a remote site.

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De/Anti-icing at Offline Stations

When de/anti-icing is required at an offline station, consult with Flight Control. Flight Control will advise the crew if the station has been trained on Delta de/anti-icing procedures.

Stations Trained on Delta De/Anti-Icing Procedures: Follow normal de/anti-icing procedures.

Stations Not Trained on Delta De/Anti-Icing Procedures: A cabin check is always required when de/anti-icing at a station not trained on Delta de/anti-icing procedures. The crew will need to confirm the following with the de/anti-icing ground crew:

- Fluid type
- Time fluid application started
- Fluid mixture, for type II/IV fluid at non-US locations
- Signal for area clear to start engines/taxi

Charter Flight De/Anti-Icing

In non-company locations, de/anti-icing of company aircraft may be accomplished by an OAL/FBO under supervision of a company employee who has successfully completed company de/anti-icing training. The company employee shall be responsible for ensuring that the de/anti-icing, all flight deck communications and all required inspections have been completed per company standards before the aircraft can be released and/or dispatched. Engine running deicing is NOT allowed in these locations and deicing shall not be performed until the flight crew arrives at the aircraft.

Exempt Stations

Due to geographical location and meteorological history, some stations are not trained in de/anti-icing. These stations are noted in a Flight Plan Remark or company pages. Delta aircraft are not permitted to be de/anti-iced at an Exempt Station.

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Aircraft or Ground Emergency Communications

Note: Both VHF and interphone must be monitored at all times.

During an aircraft or ground emergency, Delta requires that standard terminology be used to communicate specific commands.

When an aircraft or ground emergency is declared, the deicer/coordinator shall notify all aircraft on the same pad via VHF radio to shut down engines.

When an aircraft or ground emergency is declared, the captain will ensure all engines are shut down.

Aircraft Emergency

In the event of an aircraft emergency, a flight deck crewmember will contact the deicer/coordinator by interphone and VHF radio. The captain will also flash the nose taxi lights and/or any other exterior lights on and off to immediately alert ground personnel. All ground personnel will pull away from the aircraft to allow emergency vehicles to approach. Ground personnel should stand by to assist with passenger evacuation, if required.

Note: The captain will determine when a problem with the aircraft is deemed an aircraft emergency.

Note: When a deicer/coordinator verbally advises the captain of an aircraft fire, the captain will determine the appropriate action to safeguard the passengers and crew.

Ground Emergency

In the event of a ground emergency, the deicer/coordinator will contact the flight crew by interphone or by VHF radio (this may be relayed through the Iceman) and advise the captain of the nature of the ground emergency. All ground personnel will be notified by ground radio. Upon notification they will pull away from the aircraft and stand by to assist with passenger evacuation, if required.

Note: A ground emergency is defined as any problem with a deicing vehicle that affects the safety of ground crews, deicers, flight crews or passengers.

The captain is responsible for assessing if the declared ground emergency requires the declaration of an aircraft emergency. The captain will also determine if the situation requires evacuation of the aircraft.

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De/Anti-icing Fluids

Type I Fluid

Type I fluid is a deicing and anti-icing fluid with low viscosity and is considered an unthickened fluid. It forms a very thin wetting film on aircraft surfaces and has excellent deicing properties. Type I fluid can be orange-colored or colorless. Due to its low viscosity, it provides minimal anti-icing protection. Type I fluid is always diluted because adding water ensures fluid freeze point protection and ensures proper aerodynamic flow-off characteristics. Type I fluid is never applied 100 percent. Different dilution ratios of Type I fluids affect the freeze point of the fluid, but do not alter its holdover time significantly. The Type I Holdover Times Table will apply for all concentrations of this fluid.

Type II Fluid

Type II fluid is a deicing and anti-icing fluid of high viscosity and is considered a thickened fluid. It adheres to the aircraft surfaces to provide a protective film. It creates a thicker layer than Type I fluid and thus has improved anti-icing capability. Type II fluid can be straw-colored or colorless. Airflow during takeoff roll causes the fluid to shed so that by rotation the surfaces are aerodynamically clean. Varying concentration levels of Type II fluid affect its holdover time. Delta prefers to use 100 percent concentration of Type II fluid, but other concentration levels may be used at contract or overseas facilities. Not all stations will have Type II available. One of the Type II Holdover Tables will apply when this fluid is used.

Deicing ground crews may communicate a specific brand of Type II fluid, e.g., “Type II, ABAX, ECOWING 26.” Flight crews should note the fluid brand information and utilize the correct brand specific Type II Holdover Time table if it is in the De/Anti-icing Guide. If the specific brand of Type II fluid is not in the Delta De/Anti-icing Guide, or the crew is not positive as to the brand name of the fluid, default to the FAA Generic Type II Fluid table.

Type IV Fluid

Type IV fluid is an enhanced performance deicing and anti-icing fluid with characteristics similar to Type II. Type IV fluid is green colored, except in Japan, where it is colorless. Its anti-icing effectiveness is superior to Type II fluid and holdover time is increased by a significant factor under most conditions. There are separate Holdover Time Tables for Type IV which reflects this improved performance. Additionally, Type IV fluid has some unique visual characteristics. It is pale green in color and considerably thicker than Type II fluid. When applied to the wings, the extra thickness may cause the fluid to appear wavy or bumpy. Varying concentration levels of Type IV fluid affect its holdover time. Delta prefers to use 100 percent concentration of Type IV, but other concentration levels may be used at contract or overseas facilities. Not all stations will have Type IV available. One of the Type IV Holdover Tables will apply when this fluid is used.

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Deicing ground crews may communicate a specific brand of Type IV fluid e.g., "Type IV, Octagon, Max-Flight." Flight crews should note the fluid brand information and utilize the correct brand specific Type IV Holdover Time table if it is in the De/Anti-icing Guide. If the specific brand of Type IV fluid is not in the De/Anti-icing Guide, or the crew is not positive as to the brand name of the fluid, default to the FAA Generic Type IV Fluid table.

Noncertified Fluids

A de/anti-icing fluid that does not meet SAE/ISO certification requirements (including military fluids) is classified as noncertified, Type I, Type II, or Type IV fluid. These fluids may be encountered at certain international stations, or during offline operations at military bases. The use of noncertified Type I fluid is not authorized for takeoff during active icing conditions. Contact the Dispatcher if a noncertified Type I fluid is used. Noncertified Type II or Type IV fluids are not authorized under any circumstances.

Fluid Effects on Braking and Steering

Generally, Type I, Type II, and Type IV fluids are considered to have the same affect on braking and steering as water.

CAUTION: A slippery condition may exist in and around the de/anti-icing ramp and taxi ways, particularly during dry weather conditions or light precipitation.

De/Anti-icing Fluid vs. Hydraulic Fluid

It is very difficult to distinguish between de/anti-icing fluids and hydraulic fluid. In small quantities and thin coatings, both fluids will have similar coloring and feel slippery to the touch. During the exterior inspection, if residual fluids on aircraft surfaces cannot be identified, contact local Maintenance or call the MCC through the Dispatcher for guidance.

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Fluid Application Methods

De/anti-icing can be performed using a one or two step procedure.

- One step procedure - This procedure is a combination of deicing and anti-icing performed at the same time with the same fluid (de/anti-icing). The fluid used to deice the aircraft is always heated and remains on the surface to provide anti-icing protection. This procedure can be repeated so as to minimize the time required to complete the final application of fluid.
- Two step procedure - This procedure consists of two distinct fluid applications. The first step, deicing with a heated fluid, is followed by the second step, anti-icing, as a separate fluid application. Normally, Type II or Type IV fluid is used during the second step; however, Type I fluid may be used.

Note: Holdover time starts when the final application begins in either the one step or two step procedure.

Forced Air Deicing

Forced air only and forced air with Type I fluid technology utilizes an air stream to remove accumulations of frozen contaminants from the aircraft. Forced air deicing minimizes the amount of glycol used and as a result provides economic and environmental benefits.

When forced air only or forced air with Type I fluid is used as the final application, no holdover time exists.

Note: If forced air only or forced air with Type I fluid is used as the final application, it must be communicated to the captain in the Pre and Post De/Anti-icing Communication.

Engine Running De/Anti-Icing

Engine running de/anti-icing is authorized at remote locations as noted on the specific company pages. At all other stations, engine running de/anti-icing **is not authorized**. The Deicing Coordinator at the remote location is the final authority in deciding if engine running de/anti-icing will be accomplished.

An operative APU is not required for engine running de/anti-icing. During remote de/anti-icing operations at these locations, a Ground Power Unit and air start equipment will be staged at or near the remote locations. If engines need to be shut down at remote locations, immediately notify the remote pad coordinator. Ground equipment will be immediately dispatched to the aircraft to facilitate the recovery.

During light freezing rain or moderate freezing drizzle, engine running de/anti-icing at the remote locations without an operating APU is not allowed because the engines may need to be shut down to inspect the wings during de/anti-icing.

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De/Anti-icing Checks

There are four types of de/anti-icing checks: Post De/Anti-icing Check, Flight Deck Check, Cabin Check, and External Check.

Post De/Anti-icing Check

This check is an integral part of the de/anti-icing process. After aircraft de/anti-icing is complete, the deicing ground crew performs a Post De/Anti-icing Check to confirm that the critical surfaces are free of any contamination.

When the Deicer/Coord. states: “De/anti-icing, tactile inspection, and aircraft inspection complete”, this indicates that the de/anti-icing process has been completed and that all required inspections for the specific aircraft have been completed and the aircraft is contaminant free.

Flight Deck Check (Pre-Takeoff Check)

This check is an integral part of the holdover time and is performed by the pilots. Because of the limitations and cautions associated with the use of the Holdover Time Tables, the pilots must not rely on the use of holdover times as the sole determinant that the aircraft is free of contamination. They must continually assess the current weather, environmental conditions, and the aircraft’s condition. Several Flight Deck Checks are required during the holdover time period to maintain awareness of the aircraft’s condition.

The Flight Deck Check is performed by the pilots just prior to takeoff and is required anytime:

- ground icing conditions exist; and
- the holdover time is still valid.

The Flight Deck Check consists of a check of representative aircraft surfaces which are visible from the flight deck. If desired or if any doubt exists, conduct a Cabin Check.

When circumstances do not permit a satisfactory visual check from inside the aircraft, return to the designated area and:

- have ground de-icing crew perform an External Check; or
- if any doubt exists as to the condition of the aircraft, repeat the Ground De/Anti-icing procedure.

Cabin Check (Pre-Takeoff Contamination Check)

This check is performed by the pilots and is required:

- when doubt exists after conducting the Flight Deck Check;
- anytime the aircraft has been de/anti-iced, and holdover time is exceeded during conditions of frost, freezing fog, or snow;

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- during conditions of heavy snow (provided Type IV fluid has been used for anti-icing); or
- within 5 minutes of takeoff anytime a pilot-assessed change in intensity is to be used.

The Cabin Check is not authorized when the holdover time has been exceeded and the following conditions exist:

- Type I fluid has been applied during freezing drizzle, light freezing rain, or rain on cold soaked wings.
- Type II or Type IV fluid has been applied during freezing drizzle, light freezing rain, or rain on cold soaked wings. Additional de/anti-icing or an External Check must be accomplished prior to takeoff.
- Ice pellets have fallen.

The Cabin Check consists of a visual inspection of all representative aircraft surfaces which are visible from the best vantage point(s) in the cabin. Normally, de/anti-icing fluid failure will first occur on the leading or trailing edges of the wing rather than the mid-chord. Therefore, the leading edges and upper surfaces of both wings must be visually checked for evidence of fluid failure. Additionally, engine inlets must be inspected for contamination. Takeoff must occur within five minutes of the most recent check.

The ability to adequately perform this check from inside the aircraft is highly dependent upon several factors. Lighting conditions, cleanliness of cabin/flight deck windows, and outside visibility may severely hinder or prevent the pilot's ability to satisfactorily assess aircraft surfaces for contamination. When circumstances do not permit a satisfactory visual check from inside the aircraft, return to the designated area and:

- have ground de-icing crew perform the External Check.
- if any doubt exists as to the condition of the aircraft, repeat the ground de/anti-icing procedure.

External Check (Alternative Pre-Takeoff Contamination Check)

This check is performed by the de/anti-icing ground crew and is required anytime:

- doubt exists after conducting a Cabin Check; or
- the aircraft has been anti-iced with Type II or Type IV fluid, and holdover time is exceeded during freezing drizzle, light freezing rain, or rain on cold soaked wings.

This check consists of a close visual inspection of the aircraft's upper wing surfaces and leading edges for frozen contamination. Takeoff must occur within five minutes of the External Check.

If the External Check cannot be accomplished, return for additional de/anti-icing.

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CAUTION: An External Check is not authorized when Type I fluid is used during freezing drizzle, light freezing rain, or rain on cold soaked wings.

Contact local operations for specific locations on the airfield to accomplish the External Check. Be aware that some stations may conduct additional de/anti-icing as an alternative to the External Check.

Visual Indications of Loss of Fluid Effectiveness

It is difficult to determine when anti-icing fluid is beginning to fail, however, when any ice or snow, or frost can be seen accumulating on treated surfaces, the fluid has lost its effectiveness. Any ice, frost, or snow on top of deicing or anti-icing fluids must be considered as adhering to the aircraft, and additional de/anti-icing must be accomplished prior to takeoff.

- Normally, de/anti-icing fluid failure will first occur on the leading or trailing edges of the wing rather than the mid-chord. However, when the aircraft is pointing downwind the mid-chord will fail first.
- The leading edges and upper surfaces of both wings must be visually checked for evidence of fluid failure.
- If the leading edges and upper surfaces of both wings cannot be inspected from the cabin, return for an External Check or additional de/anti-icing.

Type I Fluid

When Type I fluid has lost its effectiveness, frozen precipitation will begin to accumulate on the aircraft surface in much the same manner as it would on a nontreated surface.

Type II and Type IV Fluid

When Type II or Type IV fluid has lost its effectiveness and is no longer able to absorb the freezing moisture, look for the following visual indications:

- gray or white appearance and buildup of ice crystals in or on top of the fluid;
- progressive surface freezing;
- snow accumulation;
- dulling of surface reflectiveness caused by the gradual deterioration of the fluid to slush (loss of gloss or orange peel appearance);
- ice buildup on the wing life raft attach points (if installed), adjacent to the over-wing exits.

Communication Procedures

Any airport specific deicing procedures will be contained in the Airway Manual, company pages, or noted in the Airport Remarks section of the flight plan.

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It is critical to establish communications with the ground crew prior to commencing de/anti-icing. Once the deicing operation commences, any aircraft movement or changes in configuration must be coordinated with the ground crew.

Note: At airports where Delta uses vendors or Other Airlines (OAL) for deicing, variance in Delta's standard communication may occur. This will be noted in the company pages.

Note: See the Aircraft Configuration and Communication section.

Post De/Anti-icing Communication

After de/anti-icing is complete, a report will be provided over the interphone or other means of direct communication. The use of visual signals or relayed information through a third party is NOT authorized. This report will include number of minutes since final fluid coating was started, fluid type, and fluid freeze point (Type I fluid only) or water mix ratio (Type II/IV fluid only) as well as confirmation the tactile and aircraft inspections are complete.

Note: A report is not required when the aircraft is deiced due to frost, prior to the pilot's arrival, and no active frost is forming.

Holdover Times

Use of Holdover Time Tables

Note: If no specific fluid manufacturer and type is identified in the Post De/Anti-Icing Communication, or if there is no specific HOT table for the fluid used, or there is any doubt as to the exact fluid product applied, crewmembers must default to the FAA Generic Type II or Type IV HOT table.

Holdover times provide an operational guideline for departure planning. They must be used in conjunction with the Flight Deck Check.

Holdover times published in the tables are only approximate and must be adjusted after considering all variables. The source of the Holdover Time Tables is the Aerospace Division of the Society of Automotive Engineers (SAE). Time data is derived from an analysis of testing conducted in field and laboratory conditions, as well as airline operational experience. Numerous factors affect the actual time that anti-icing fluid will provide protection against frozen contamination.

The times specified in the tables represent the approximate holdover times for seven categories of active precipitation.

- Frost
- Freezing fog
- Snow/Snow Grains/Snow Pellets
- Freezing drizzle

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- Freezing rain (light).
- Ice pellets
- Rain on cold soaked wings.

Three precipitation categories specify a time range (snow, freezing drizzle, and rain on cold soaked wings), and four categories specify a single time (freezing fog, frost, light freezing rain and ice pellets).

Whenever a time range is given, the lower time in the range is for moderate precipitation conditions and the upper time is for light conditions.

When a single time is specified in the table, it represents the approximate holdover time limit for that weather condition. However, it may be necessary to adjust the holdover time downward after considering other environmental factors.

Establishing Holdover Time

A holdover time is established using the following five steps.

1. Complete the Post De/Anti-icing Communication. The following data from the communication is used to establish a holdover time:

- Fluid type. When Type II, or Type IV fluids are used, the anti-icing fluid manufacturer's name and product type name will be given. If the specific brand of fluid is not in the Delta De/Anti-Icing Guide, or if the crew is not positive as to the brand name of the fluid, default to the FAA Generic Type II/IV Fluid table.
- Concentration (Non-US stations for Type II and Type IV only). There are no fluid mixture breakouts on the Type I Holdover Time Table because dilution ratios do not significantly affect holdover time for Type I fluids.
- Time since the final anti-icing began. The holdover timing starts when the final (anti-icing) fluid application began.

2. Determine the current weather conditions (OAT, type of precipitation, and intensity of precipitation).

- In snowfall conditions, refer to the De/Anti-Icing guide to determine snowfall intensity.
- OAT is determined by the most current weather report or ATIS.
- The Holdover tables allow pilots to determine holdover times based partly upon the type and intensity of the frozen precipitation that is falling.
- The type and intensity of frozen precipitation (light, moderate, or heavy) is officially determined by the most current official weather report (e.g., from National Weather Service [NWS]. NWS-approved automated system, or other agent approved by the NWS).
- If at any time a pilot assesses intensity greater than that being reported, he/she shall use the heavier precipitation when entering the holdover tables for holdover time.

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- If, in the pilot's judgment, the intensity is less than that being reported, the pilot shall request (e.g., to the tower or trained weather observer) a new observation be taken and reported or shall wait long enough for an update to an automated meteorological observation to be taken and reported as applicable.
  - A pilot may act on their own assessment of lesser precipitation intensity only in those cases concerning snowfall or ice pellets where the officially reported (e.g., from NWS, NWS-approved automated system, or other agent approved by the NWS) meteorological precipitation intensity is grossly different from that which is obviously occurring. (For example: precipitation is reported when there is no actual precipitation occurring.)
  - If an adjustment to intensity is pilot-assessed, the pilots shall communicate the newly assessed intensity to Flight Control via ACARS.
  - If a pilot acts based upon their own assessment that precipitation intensity levels are LOWER than the official reported intensity level, a Cabin Check is required within the 5 minutes preceding takeoff.
- Pilot assessment of precipitation intensity levels may only be used when there is enough natural sunlight or artificial lighting available to provide adequate exterior visibility. All windows through which the assessment is made must be adequately transparent so as to not restrict the pilot's visibility under the lighting conditions present.
- The Snowfall Intensities as a Function of Prevailing Visibility chart in the De/Anti-icing Guide, Flight Crew Operations Manual, is based on prevailing visibility and allowances are made for the effects of night light conditions.
- Ice pellet intensity shall be assessed using the following criteria:
  - light - scattered pellets that do not completely cover exposed surfaces regardless of duration;
  - moderate - slow accumulation on the ground;
  - heavy - rapid accumulation on the ground.
- Pilots are not permitted to self-assess intensity in the case of reported freezing drizzle or freezing rain unless no precipitation is actually falling. Freezing drizzle and freezing rain quickly adhere to cold surfaces and can be difficult to see; for this reason, if conditions are reported or anticipated the aircraft shall be de-iced and/or treated with anti-icing fluid as a precaution against encountering these conditions during taxi-out.

3. Based on all the information obtained in steps 1 and 2, reference the appropriate Holdover Time Table and determine:

- a single time from the frost, freezing fog, light freezing rain or ice pellets column; or
- a time range from the snow, freezing drizzle, or rain on cold soaked wings column.

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4. If a single time was extracted from the table, go to step 5. If a time range was extracted, determine a specific holdover time from this range by assessing:

- Intensity of precipitation. As a general rule, holdover time ranges should be interpreted as follows:
  - light conditions = upper end of time range;
  - moderate conditions = lower end of time range;
  - heavy conditions = less than the lower time value.
- When determining intensity, the pilots must consider the rate, density, and moisture content of the precipitation. For example, wet snow is considered more intense than dry/powdery snow and will have a lower holdover time. Wet snow occurs at or near freezing temperatures of -1°C (30°F) or above.

5. Further refine the determined holdover time after considering the following additional factors:

- Environmental factors - Jet blast, high wind velocity, and wind direction may cause anti-icing fluid to flow off aircraft surfaces thus reducing holdover time. Blowing snow due to wind or jet blast could decrease holdover time by increasing the amount of precipitation contacting aircraft surfaces and diluting the fluid. Solar radiation from direct sunlight may increase holdover time by warming aircraft surfaces.
- Aircraft skin temperature - Although this is difficult to determine, pilots need to be aware that aircraft skin temperature lower than OAT may decrease holdover time. One of the best ways to assess wing skin temperature is by referencing the fuel temperature, if available. Fuel temperature significantly lower than OAT may decrease holdover time.
- Operational experience of the pilots - For example, pilots who rarely fly in ground icing conditions may feel more comfortable using more conservative holdover times. Additionally, any background knowledge or experiences can be applied by the pilots.

Adjusting Holdover Time

A continuous assessment of weather and environmental conditions in conjunction with the Flight Deck Check is required during the holdover time period. Changing conditions may increase or decrease fluid effectiveness, necessitating a holdover time adjustment.

- A change in OAT.
- A change in type or intensity (rate or density) of precipitation. Snow changing to light freezing rain, or light snow changing to heavy snow will decrease holdover time. Conversely, moderate snow changing to light snow may increase holdover time. Presence of ice pellets precipitation may necessitate similar adjustment.
- Jet blast, an increase in wind velocity, or a change in wind direction will decrease holdover time.

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Exceeding Holdover Time

The captain is responsible for monitoring the status of the aircraft exterior for frozen contamination. The pilot performs periodic Flight Deck Checks to ensure the aircraft is free of contamination during the time between anti-icing and takeoff, whenever the holdover time is still valid.

When holdover time is exceeded, the required course of action will depend upon the type of active precipitation and the type of fluid used to anti-ice. Refer to the current De/Anti-Icing Guide booklet for additional specific guidance.

Required Action When Holdover Time is Exceeded

<table>
<tr><th rowspan="2">Fluid Used to Anti-Ice</th><th colspan="6">Active Precipitation</th></tr>
<tr><th>Frost</th><th>Freezing Fog</th><th>Snow, Snow Grains, Snow Pellets</th><th>Freezing Drizzle</th><th>Light Freezing Rain</th><th>Rain on Cold Soaked Wings</th></tr>
<tr><td>Type I</td><td colspan="3" rowspan="2">Accomplish one of the following actions:
A Cabin Check,
An External Check, or
Additional De/Anti-Icing</td><td colspan="3">Takeoff Not Authorized</td></tr>
<tr><td>Type II or Type IV</td><td colspan="3">Accomplish one of the following actions:
An External Check, or
Additional De/Anti-Icing</td></tr>
</table>

Configuring the Aircraft for De/Anti-icing

It is the responsibility of the pilots to ensure the aircraft is properly configured prior to commencing de/anti-icing operations.

Note: Whenever de/anti-icing will occur during overnight parking, the pilots must ensure the aircraft is properly configured prior to leaving for the night. Refer to Vol. 1, SP.16, Cold Weather Operation, Secure Procedure.

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Takeoff and Initial Climb — Chapter 3
Table of Contents — Section TOC

Takeoff 3.1
Takeoff - General 3.1
Initiating Takeoff Roll 3.1
Rotation and Liftoff - All Engines 3.4
Effect of Rotation Speed and Pitch Rate on Liftoff 3.5
Center-Of-Gravity Effects 3.5

Crosswind Takeoff 3.6
Takeoff Crosswind Guidelines 3.6
Directional Control 3.6
Rotation and Takeoff 3.6
Gusty Wind and Strong Crosswind Conditions 3.7

Reduced Takeoff Thrust (Less Than Normal Power) 3.7
Assumed Temperature Method (ATM) 3.8
Derated Takeoff Thrust (Fixed Derate) 3.8
Combination ATM and Fixed Derate 3.8
Thrust Control 3.8

Low Visibility Takeoff 3.9

Post De/Anti-Icing Takeoff 3.9

Adverse Runway Conditions 3.9

Takeoff Performance Limit Weights 3.10

Rejected Takeoff Decision 3.11
Rejected Takeoff Maneuver 3.13
Go/Stop Decision Near V1 . . . . . 3.15

Tail Strike 3.16
Takeoff Risk Factors 3.17

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Initial Climb - All Engines 3.18
Minimum Fuel Operation for Takeoff 3.18
Immediate Turn after Takeoff - All Engines 3.18
Roll Modes 3.19
Pitch Modes 3.19
Autopilot Engagement 3.20
Flap Retraction Schedule 3.20
Normal Takeoff Profile (Distant/ICAO NADP 2) 3.21
Special Takeoff Profile (Close-In/ICAO NADP 1) 3.24
Noise Abatement Takeoff 3.26

Takeoff - Engine Failure 3.27
Engine Failure Recognition 3.27
Rotation and Liftoff - One Engine Inoperative 3.27
Initial Climb - One Engine Inoperative 3.28
Immediate Turn after Takeoff - One Engine Inoperative 3.28
Autopilot Engagement - One Engine Inoperative 3.29
Acceleration Height - One Engine Inoperative 3.29
Diverting to an Alternate - One Engine Inoperative 3.30
Takeoff Profile - Engine Failure 3.31
Engine Failure During an ATM Takeoff 3.34

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Takeoff

Normal takeoff procedures (NADP2 profile) satisfy typical noise abatement requirements. Some airports may have special procedures (NADP 1 profile or company pages) which require modification of the takeoff profile.

Takeoff - General

Review the TAKEOFF REF page to ensure the entries are correct. Ensure V2 is set on the MCP. The map display, map range, and LEGS page sequence should be consistent with the departure procedure.

Review the LEGS page for any climb constraints. Ensure the CLB page contains the appropriate altitude and airspeed restrictions consistent with the departure procedure.

Progress page 2 should be monitored during RNAV departures for crosstrack error. To reduce heads down activity, climb constraint modification immediately after takeoff should normally be accomplished on the MCP. Modify the CLB page when workload permits.

Note: When both engines are operating above 64% N1 and the ART system READY light is illuminated, selecting alternate position on the DFGC will activate the ART system on both engines.

Initiating Takeoff Roll

Autothrottle and flight director use is recommended for all takeoffs. However, do not follow F/D commands until after liftoff.

Rolling Takeoff

CAUTION: Rolling takeoffs are not permitted in icing or low visibility conditions.

A rolling takeoff while setting takeoff thrust is recommended. It expedites the takeoff and reduces the risk of foreign object damage or engine surge/stall due to a tailwind or crosswind. Flight test and analysis prove that the change in takeoff roll distance due to the rolling takeoff procedure is negligible when compared to a standing takeoff.

A rolling takeoff is accomplished by maintaining normal taxi speeds when cleared for takeoff before or while entering the runway. When the aircraft is aligned with the runway centerline ensure the nose wheel steering is released and apply takeoff thrust by advancing the throttles to approximately (88) 1.4 EPR, (90) 1.2 EPR. Allow the engines to stabilize momentarily select autothrottles and follow the throttles through autothrottle application of takeoff thrust.

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Static Takeoff

A static takeoff is accomplished by holding in position on the assigned runway. Ensure the nose wheel steering tiller is released and release brakes, then apply takeoff thrust as described above. This method satisfies the criteria for takeoff minima in low visibility.

Note: Brakes are not normally held with thrust above idle unless a standing takeoff in icing conditions is required.

Standing Takeoff

A standing takeoff is accomplished by holding the brakes until the engines are (88) 70%, (90) 50% N1.

Ensure the nose wheel steering wheel is released, then gently release the brakes and promptly select autothrottles and follow the throttles through autothrottle application of takeoff thrust.

All Takeoffs

CAUTION: Do not engage autothrottles until both engines have stabilized.

Allowing the engines to stabilize momentarily prior to advancing to takeoff thrust provides uniform engine acceleration to takeoff thrust and minimizes directional control problems. This is particularly important if crosswinds exist or the runway surface is slippery. The exact initial setting is not as important as setting symmetrical thrust. If thrust is to be set manually, smoothly advance throttles toward takeoff thrust.

Note: During tailwind conditions, slight EPR (as installed) fluctuations may occur on some engines before 5 knots forward airspeed.

Note: Allowing the engines to stabilize for more than approximately 2 seconds before advancing throttles to takeoff thrust may adversely affect takeoff distance.

The PM should verify that takeoff thrust has been set and the throttle hold mode (CLMP) is engaged. Once CLMP annunciates, the autothrottle cannot change throttle position, but throttles can be positioned manually. The CLMP mode remains engaged until another thrust mode is selected.

Note: Takeoff into headwind of 20 knots or greater may result in CLMP before the autothrottle can make final thrust adjustments.

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Ensure the target EPR is set by 80 knots. Minor increases in thrust may be made immediately after. After takeoff thrust is set, a small deviation in N1 between the engines should not warrant a decision to reject the takeoff unless this deviation is accompanied by a more serious event. Due to variations in engine types, thrust settings, runway conditions, etc., it is not practical to specify a precise tolerance for EPR differences between the engines.

Acceleration time from idle to the initial thrust setting can vary among engines because of differences in engine bleed configuration or fuel control acceleration schedules. Variations of up to three seconds are considered acceptable.

Note: If the throttles clamp prior to takeoff EPR, advance the throttles manually.

Use of the nose wheel steering wheel is not recommended above 30 knots. However, pilots must use caution when using the nose wheel steering tiller above 20 knots to avoid over-controlling the nose wheels resulting in possible loss of directional control.

The CLMP mode protects against throttles movement if a system fault occurs. Lack of the CLMP annunciation means the protective feature may not be active. If CLMP annunciation does not appear, no crew action is required unless a subsequent system fault causes unwanted throttles movement. As with any autothrottle malfunction, the autothrottle should then be disconnected and desired thrust set manually.

Light forward pressure is held on the control column. Keep the aircraft on centerline with rudder pedal steering and rudder. The rudder becomes effective between 40 and 60 knots. Maximum nose wheel steering effectiveness is available when above taxi speeds by using rudder pedal steering.

Regardless of which pilot is making the takeoff, the captain should keep one hand on the throttles until V1 in order to respond quickly to a rejected takeoff condition. After V1, the captain's hand should be removed from the throttles.

The PM should monitor engine instruments and airspeed indications during the takeoff roll and announce any abnormalities. Pilots should use N1 RPM to verify EPR gauge readings. In a normal situation, N1 verifies that the EPR being used by the autothrottles is accurate. If N1 is lower than expected, it may indicate an inop/frozen EPR gauge and power may need to be adjusted to achieve the appropriate N1. An inop/frozen EPR gauge with no other associated non-normal engine indications is not a reason to abort above 80 KIAS on takeoff. The PM should announce passing 80 knots and the PF should verify that his airspeed indicator is in agreement.

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A pitot system blocked by protective covers or foreign objects can result in no airspeed indication, or airspeed indications that vary between instruments. It is important that aircrews ensure airspeed indicators are functioning and reasonable at the 80 knot callout. If the accuracy of either primary airspeed indication is in question, reference the standby airspeed indicator. Another source of speed information is the ground speed indication. Early recognition of a malfunction is important in making a sound go/stop decision. Refer to the Airspeed Unreliable section in chapter 8 for an expanded discussion of this subject.

Rotation and Liftoff - All Engines

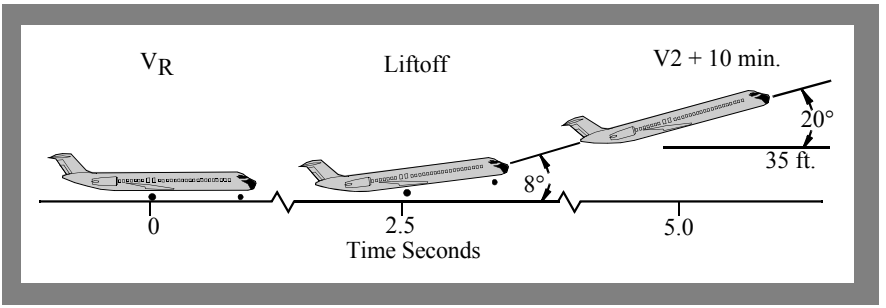
Takeoff speeds are established based on minimum control speed, stall speed, and tail clearance margins. Shorter-bodied aircraft are normally governed by stall speed margin while longer-bodied aircraft are normally limited by tail clearance margin. When a smooth continuous rotation is initiated at VR, tail clearance margin is assured because computed takeoff speeds depicted in the WDR or ODM are developed to provide adequate tail clearance.

Above 80 knots, relax the forward control column pressure to the neutral position. At VR, commence a smooth, continuous rotation (approximately 3° per second) to attain a speed of V2 + 10 knot minimum, limiting pitch to 20°. Slow or fast rotation will significantly degrade takeoff performance. After liftoff use the flight director as the primary pitch reference, cross checking indicated airspeed and other flight instruments. Takeoffs at low thrust setting (low excess energy) will result in a lower initial pitch attitude target to achieve the desired climb speed.

Note: The flight director pitch command is not used for rotation.

Typical Rotation, All Engines

The following figure shows typical rotation with all engines operating.



Retract the landing gear after a positive rate of climb is indicated on the altimeter.

Retract flaps in accordance with the technique described in this chapter.

CAUTION: The tailskid will contact the runway at 10.5° nose up.

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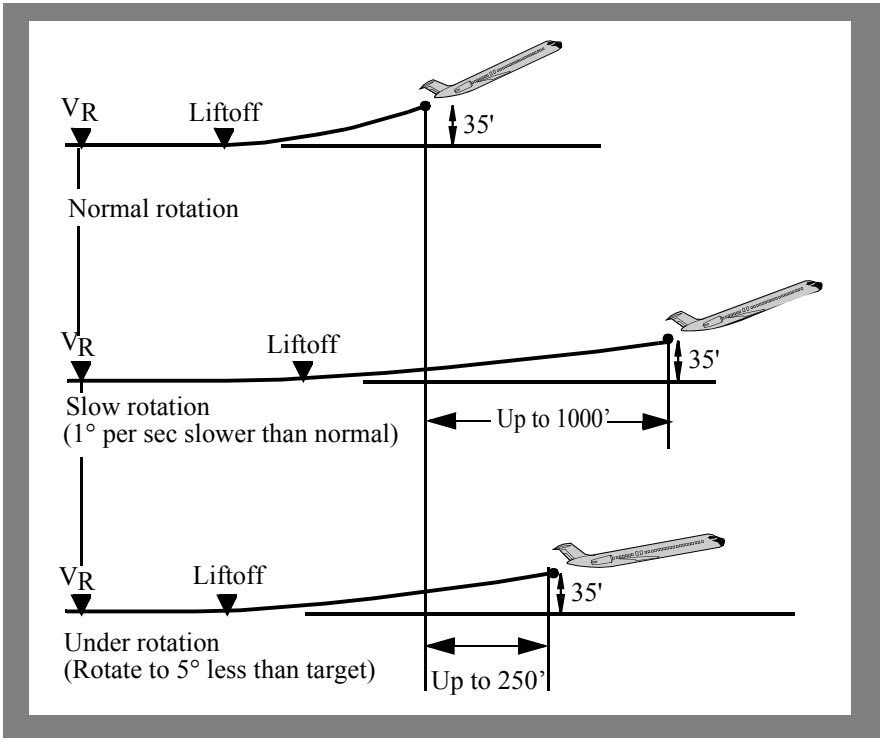
Effect of Rotation Speed and Pitch Rate on Liftoff

Takeoff and initial climb performance depend on rotating at the correct airspeed and proper rate to the rotation target attitude. Early or rapid rotation may cause a tail strike. Late, slow, or under-rotation increases takeoff ground roll. Any improper rotation decreases initial climb flight path.

The following diagram shows how a slow or under rotation during takeoff increases the distance to a height of 35 feet compared to a normal rotation.

Slow or Under Rotation (Typical)



Center-Of-Gravity Effects

When taking off at light weight and with an aft CG, the combination of full thrust, rapid thrust application, and sudden brake release may tend to pitch the nose up, reducing nosewheel steering effectiveness. With CG at or near the aft limit, maintain forward pressure on the control column until 80 knots to increase nosewheel steering effectiveness. Above 80 knots, relax the forward control column pressure to the neutral position. At light weight and aft CG, use of reduced thrust and rolling takeoff technique is recommended whenever possible. The rudder becomes effective between 40 and 60 knots.

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Aircraft with an aft CG and trimmed erroneously for “nose up” may cause a premature rotation increasing the possibility of a tail strike.

Crosswind Takeoff

Engine surge can occur with a strong crosswind or tailwind component if takeoff thrust is set before brake release. Therefore, the rolling takeoff procedure is strongly advised when crosswinds exceed 20 knots.

Takeoff Crosswind Guidelines

Takeoff crosswind guidelines are based on the most adverse aircraft loading (light weight and aft center of gravity) and assume an engine out RTO and proper pilot technique.

For contaminated runways, refer to Volume 1, SP.16, Guidelines for Takeoff on Contaminated Runways or Landing with Braking Action Less than Good, Crosswind Guidance.

Directional Control

Initial runway alignment and smooth symmetrical thrust application result in good crosswind control capability during takeoff. Light forward pressure on the control column during the initial phase of the takeoff roll (below approximately 80 knots) increases nose wheel steering effectiveness. Any deviation from the centerline during thrust application should be countered with immediate, smooth, and positive control inputs. Smooth rudder control inputs combined with small control wheel inputs result in a normal takeoff with no overcontrolling.

Note: With wet or slippery runway conditions, the PM should give special attention to ensuring the engines have symmetrically balanced thrust indications.

Rotation and Takeoff

Begin the takeoff roll with the control wheel displaced into the wind only enough to maintain approximately wings level.

Note: Excessive control wheel displacement during rotation and liftoff increases spoiler deployment. As spoiler deployment increases, drag increases and lift is reduced which results in reduced tail clearance, a longer takeoff roll, and slower aircraft acceleration.

At liftoff, the aircraft is in a sideslip with crossed controls. A slow, smooth recovery from this sideslip is accomplished by slowly neutralizing the control wheel and rudder pedals after liftoff.

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Gusty Wind and Strong Crosswind Conditions

For takeoff in gusty or strong crosswind, consider the use of a higher thrust setting than the minimum required. When the prevailing wind is at or near 90° to the runway, the possibility of wind shifts resulting in gusty tailwind components during rotation or liftoff increases. During this condition, consider the use of thrust settings close to or at maximum takeoff thrust. The use of a higher takeoff thrust setting reduces the required runway length and minimizes the aircraft exposure to gusty conditions during rotation, liftoff, and initial climb.

Gusty wind conditions require rotation at less than normal rates. Increased airspeed at rotation (not to exceed normal VR + 20) improves the ability of the aircraft to negotiate a windshear encountered after liftoff. Increased airspeed improves the flight path, reduces potential exposure to flight near stick shaker speeds, and reduces pilot workload.

If a gust is experienced near VR, as indicated by stagnant airspeed or rapid airspeed acceleration, momentarily delay rotation. This slight delay allows the aircraft additional time to accelerate through the gust and the resulting additional airspeed improves the tail clearance margin. Do not rotate early or use a higher than normal rotation rate in an attempt to clear the ground and reduce the gust effect because this reduces tail clearance margins. Limit control wheel input to that required to keep the wings level. Use of excessive control wheel increases spoiler deployment which has the effect of reducing tail clearance. All of these factors provide maximum energy to accelerate through gusts while maintaining tail clearance margins at liftoff. The aircraft is in a sideslip with crossed controls at this point. A slow, smooth recovery from this sideslip is accomplished after liftoff by slowly neutralizing the control wheel and rudder pedals.

Reduced Takeoff Thrust (Less Than Normal Power)

Note: The term “Assumed Temperature Method (ATM)” is synonymous with the term “FLEX.”

Normally, takeoffs are conducted with less than normal takeoff thrust whenever performance capabilities permit. Lower takeoff thrust reduces EGT, improves engine reliability, and extends engine life.

Takeoff thrust reduction can be achieved using Assumed Temperature Method (ATM). Takeoff with less than normal takeoff thrust complies with all regulatory takeoff performance requirements. The thrust reduction authorized by most regulatory agencies is limited to 25% below any certified takeoff thrust rating. At any time during takeoff, throttles may be advanced to the normal takeoff thrust. Regardless of the method, use the takeoff speeds provided on the WDR corresponding to the specific thrust setting being used.

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Assumed Temperature Method (ATM)

CAUTION: Do not use ATM when:

- **Restricted at particular airports; refer to company pages**
- **Unstable weather conditions exist**
- **AWABS is inoperative**
- **Runway is contaminated with standing water, slush, snow or ice**
- **Certain MEL (O) PROCEDURES prohibit its use**
- **An ATM thrust setting is not authorized by the WDR.**

ATM is achieved by selecting an assumed temperature higher than the actual ambient temperature. Some or all reduced thrust settings may not be available on colder days. Higher assumed temperatures result in takeoff EPR less than Max Climb EPR. (88) The AWABS will not set an ATM EPR less than Climb EPR.

When using ATM, the takeoff thrust setting is not considered a takeoff operating limit since minimum control speeds (VMCG and VMCA) are based on the normal takeoff thrust. At any time during takeoff, throttles may be advanced to the normal takeoff thrust.

Actual performance is equal to or better than the performance obtained if actually operating at the assumed temperature. This is because the true airspeed at the actual temperature is lower than at the assumed temperature.

Derated Takeoff Thrust (Fixed Derate)

90

The aircraft has the capability to perform a derated thrust takeoff. However, Delta Air Lines does not currently use or permit using derated takeoff thrust.

Combination ATM and Fixed Derate

90

The aircraft has the capability to perform a combined ATM and fixed derate thrust takeoff. However, Delta Air Lines does not currently use or permit using combined ATM and derated takeoff thrust.

Thrust Control

When conducting an ATM takeoff, if more thrust is needed (up to maximum thrust) when thrust is in CLMP mode, throttles must be advanced manually. If conditions are encountered during the takeoff where additional thrust is needed, such as a windshear condition, the crew should not hesitate to manually advance throttles to the required higher thrust setting.

The aircraft has the capability to perform a derated thrust takeoff. However, Delta Air Lines does not currently use or permit using derated takeoff thrust.

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Low Visibility Takeoff

Low visibility takeoff operations may require a takeoff alternate. When selecting a takeoff alternate, consideration should be given to unexpected events such as an engine failure or other non-normal situation that could affect landing minima at the takeoff alternate.

With appropriate runway lighting and/or markings, takeoffs with visibility as low as 500ft/150m RVR may be authorized (FAA). Regulatory agencies may apply takeoff crosswind limits specifically for low visibility takeoffs.

Note: Consider an autoland system test.

Refer to the FOM, chapter 5.1, Alternate Designation Criteria.

Refer to the Airway Manual, Ops Specs, Takeoff Minima.

Post De/Anti-Icing Takeoff

Testing of undiluted de-icing/anti-icing fluids has shown that some of the fluid remains on the wing during takeoff rotation and initial climb. The residual fluid causes a temporary decrease in lift and increase in drag. However, the effects are temporary. Use the normal takeoff rotation rate. Snow (wet or dry), slush, standing water, and ice will adversely affect takeoff performance. Slush, dry snow, and standing water affect acceleration. Precipitation in any form affects stopping capability.

Adverse Runway Conditions

Slush, standing water, or deep snow reduces the aircraft takeoff performance because of increased rolling resistance and reduced tire-to-ground friction. In addition to performance considerations, slush or standing water may cause damage to the aircraft. The maximum depth for slush, standing water, or wet snow is 0.5 inch on the runway. For dry snow the maximum depth is 4 inches. To determine runway condition for takeoff, refer to Vol. 1, SP.16, Guidelines for Contaminated Runways, Takeoff Runway Contaminant Decision Tree.

A slippery runway (wet, compact snow, ice) also increases stopping distance during a rejected takeoff. Takeoff performance and critical takeoff data are adjusted to fit the existing conditions. Check the WDR for takeoff performance changes with adverse runway conditions.

Note: If there is an element of uncertainty concerning the safety of an operation with adverse runway conditions, do not takeoff until the element of uncertainty is removed.

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During wet runway or slippery conditions, give special attention to ensure that the thrust on the engines advances symmetrically. Any tendency to deviate from the runway centerline must immediately be countered with steering action.

Forward pressure on the control column during the initial portion of the takeoff roll increases nose wheel steering effectiveness. After 70 knots during takeoff roll, reduce forward pressure on control column to reduce spray from the nosewheel.

During takeoffs on icy runways, lag in rudder pedal steering and possible nose wheel skidding must be anticipated. Keep the aircraft on the centerline with rudder pedal steering and rudder. The rudder becomes effective between 40 - 60 knots. If deviations from the centerline cannot be controlled either during the start of the takeoff roll or until the rudder becomes effective, immediately reject the takeoff.

Refer to Vol. 1, SP.16, Guidelines for Contaminated Runways.

Takeoff Performance Limit Weights

The Takeoff Performance Limit Weights required by the FARs include:

- Climb Limit Weight
- Obstacle Clearance Limit Weight
- Field Length Limit Weight (which include tire speed and brake energy limits)

The Climb Limit Weight assures that a specified gradient can be maintained after liftoff in still air conditions. The Obstacle Clearance Limit Weight assures that all obstacles along the intended flight path can be cleared with one engine inoperative. The Field Length Limit Weight is the most restrictive weight resulting from the following runway length requirements:

- The distance required to accelerate with all engines, experience an engine failure within 1 second of V1, continue the takeoff to a height 35 feet above the runway at V2 speed (Accelerate-Go Distance).
- The distance required to accelerate with all engines, recognize an event within 1 second of V1, initiate the stopping maneuver and stop within the confines of the runway (Accelerate-Stop Distance).
- 1.15 times the all engine takeoff distance required to reach a point 35 feet above the runway (usually only limiting for 4-engine aircraft).

Delta presents the Climb Limit Weight (CLW) separately on the Weight Data Record (WDR). The Field Length Limit and the Obstacle Clearance Limit are combined into one Runway Allowable Takeoff Weight (RATOW). Headwind and tailwind corrections apply to the RATOW but not the CLW.

The FAR requirements are based on certification flight tests on a dry runway using maximum braking but do not include credit for reverse thrust. Performance limits for wet and contaminated runways do include credit for the use of reverse thrust.

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By definition, all V1 speeds result in accelerate-go distance equal to accelerate-stop distance. Balanced Field Length occurs when the accelerate-go (or accelerate-stop distance) is equal to the length of the available runway. This generally results in the maximum Field Length Limit Weight but not necessarily the maximum RATOW or maximum takeoff weight considering both CLW and RATOW.

Takeoff flaps are chosen to give the best balance of performance considering the Field Length Limits and the climb limits associated with the Climb Limit Weight and the Obstacle Clearance Limit. Larger takeoff flaps reduce the stall speed but increase the drag, so they give better Field Length Limits at the expense of climb performance. Larger flap settings also provide greater tail clearance because liftoff occurs at a smaller angle of attack. Smaller takeoff flap settings give better climb performance but require longer field lengths. RATOW does not necessarily increase or decrease with flap setting changes because it includes both Field Length and Obstacle Clearance (climb) considerations.

Rejected Takeoff Decision

The total energy that must be dissipated during an RTO is proportional to the square of the aircraft velocity. At low speeds (up to approximately 80 knots), the energy level is low. Therefore, the aircraft should be stopped if an event occurs that would be considered undesirable for continued takeoff roll or flight. Examples include Master Caution, unusual vibrations, or tire failure.

As the airspeed approaches V1 during a balanced field length takeoff, the effort required to stop can approach the aircraft maximum stopping capability. Therefore, the decision to stop must be made before V1.

Historically, rejecting a takeoff near V1 has often resulted in the aircraft stopping beyond the end of the runway. Common causes include initiating the RTO after V1 and failure to use maximum stopping capability (improper procedures/techniques). The maximum braking effort associated with an RTO is a more severe level of braking than most pilots experience in normal service.

Rejecting the takeoff after V1 is not recommended unless the captain judges the aircraft incapable of flight. Even if excess runway remains after V1, there is no assurance that the brakes have the capacity to stop the aircraft before the end of the runway.

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The takeoff should be rejected for the following:

Event	Prior to 80 knots	80 knots to V1	Above V1
Activation of the Master Caution or Warning	X		
System Failures	X		
Unusual noise or vibration	X		
Tire Failure	X		
Abnormally slow acceleration	X		
Takeoff configuration warning	X		
If a side window opens	X		
Engine failure	X	X	
Fire or fire warning	X	X	
Predictive windshear caution or warning*	X	X	
If the aircraft is unsafe or unable to fly	X	X	X

*Refer to chapter 7, Windshear.

If the captain is making the takeoff, the captain must:

- clearly announce “ABORT,” and
- immediately start the Rejected Takeoff Maneuver.

When the first officer is making the takeoff and the captain decides to abort, the captain must:

- clearly announce “ABORT, I HAVE THE AIRCRAFT,”
- immediately start the Rejected Takeoff Maneuver, and
- assume control of the aircraft in a positive manner.

Note: The first officer will maintain directional control of the aircraft until the captain makes a positive input to the controls and states, “I HAVE THE AIRCRAFT.”

Note: Do not abort takeoff for door light indication.

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Rejected Takeoff Maneuver

The RTO maneuver is initiated during the takeoff roll to expeditiously stop the aircraft on the runway. The PM should closely monitor essential instruments during the takeoff roll and immediately announce abnormalities, such as “ENGINE FIRE”, “ENGINE FAILURE”, or any adverse condition significantly affecting safety of flight. The decision to reject the takeoff is the responsibility of the captain, and must be made before V1 speed. If the captain is the PM, he should initiate the RTO maneuver and then, as time permits, announce the abnormality.

If the takeoff is rejected before the CLMP annunciation, the autothrottle should be disconnected as the throttles are moved to idle. If the autothrottle is not disconnected, the throttles advance to the selected takeoff thrust position when released. After CLMP is annunciated, the throttles, when retarded, remain in idle. For procedural consistency, disconnect the autothrottles for all rejected takeoffs.

During a rejected takeoff with TO selected, below (90) 90, (88) 70 knots MIN braking is provided. Above (90) 90, (88) 70 knots, TO braking will provide maximum braking.

After an RTO, complete any required non-normal checklist and refer to the QRH, section 0, Rejected Takeoff - Post RTO Considerations.

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Rejected Takeoff Maneuver Table

Captain	First Officer
Without delay: • Retard throttles to IDLE • Disengage the autothrottles • Apply maximum reverse thrust consistent with conditions	Verify actions as follows: • Ensure throttles to IDLE • Autothrottles disengage • Verify reverse thrust applied.
Extend ground spoilers (if not deployed)	SPD BRK lever aft Call "SPOILERS UP" If SPD BRK lever not aft, Call "NO SPOILERS"
Apply maximum wheel brakes (AUTO or Manual) **Note:** If TO autobrakes is selected, monitor performance and apply manual wheel brakes as required.	Verify maximum brakes applied
Continue maximum braking until certain the airplane will stop on the runway.	Call out any omitted action items.
Field length permitting, Initiate movement of the thrust reverser levers to reach the reverse idle detent by taxi speed.	Call “80 KNOTS”
Notify the tower of the abort and request emergency equipment, if necessary. As soon as practical, make the appropriate RTO PA in accordance with the FOM.	

CAUTION: If difficulty in maintaining directional control is experienced during reverse thrust operation, reduce reverse thrust to reverse idle (or forward idle thrust if required), regain directional control, and reapply reverse thrust as necessary. Do not attempt to maintain directional control by using asymmetrical reverse thrust.

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Post RTO Considerations

- Tower Notification: Once stopping is assured, notify ATC. Should a high energy (high speed, heavy weight) RTO occur, consider requesting emergency equipment be dispatched to meet the aircraft in the event of possible tire or brake fire.
- Airport Rescue and Fire Fighting (ARFF): ARFF personnel can provide important information regarding the exterior status of the aircraft. Refer to the FOM, Chapter 6 for hand signals used by ARFF personnel. Consider remaining on the runway if emergency equipment is needed.
- RTO PA: If an evacuation is not required, make a PA as soon as practical. A second PA should be made after the situation has stabilized. If an evacuation is required, make a PA when directed by the Emergency Evacuation checklist.
- Non-Normal Checklists: Complete the Non-Normal checklist (if appropriate) for the condition(s) causing the RTO.
- Prior to taxi: Check entry/exit door status to ensure an evacuation is not in progress. Ensure ground personnel and equipment are clear of the aircraft.
- Parking Brake: Consider not setting the parking brake to facilitate brake cooling and reduce the possibility of brakes fusing. Consider setting the parking brake to ensure the safety of ground personnel or as directed by the Evacuation checklist.
- Brake Cooling: Observe brake cooling schedule and precautions in the ODM.
- Subsequent Departures: Contact Flight Control and refer to FOM, Chapter 3.4, Rejected Takeoff (RTO).
- Refer to the QRH, section 0, Rejected Takeoff - Post RTO Considerations.

Go/Stop Decision Near V1

It was determined when the aviation industry produced the Takeoff Safety Training Aid in 1992 that the existing definition of V1 might have caused confusion because they did not make it clear that V1 is the maximum speed at which the flight crew must take the first action to reject a takeoff. The U.S. National Transportation Safety Board (NTSB) also noted in their 1990 study of rejected takeoff accidents that late initiation of rejected takeoffs was the leading cause of runway overrun accidents. As a result, the FAA has changed the definition of V1 in FAR Part 1 to read as follows:

- V1 means the maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speedbrakes) to stop the aircraft within the accelerate-stop distance and
- V1 also means the minimum speed in the takeoff, following a failure of an engine at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.

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Pilots know that V1 is fundamental to making the Go/Stop decision. Under runway limited conditions, if the reject procedure is initiated at V1, the aircraft can be stopped before reaching the end of the runway.

When the takeoff performance in the AFM is produced, it assumes an engine failure or event one second before V1. In a runway limited situation, this means the aircraft reaches a height of 35 feet over the end of the runway if the decision is to continue the takeoff.

Within reasonable limits, even if the engine failure occurs earlier than the assumed one second before V1, a decision to continue the takeoff will mean that the aircraft is lower than 35 feet at the end of the runway, but it is still flying. For example, if the engine fails 2 seconds before V1 and the decision is made to go, the aircraft will reach a height of 15 to 20 feet at the end of the runway.

Although training has historically centered on engine failures as the primary reason to reject, statistics show engine thrust loss was involved in approximately one quarter of the accidents, and wheel or tire problems have caused almost as many accidents and incidents as have engine events. Other reasons that rejects occurred were for configuration, indication or light, crew coordination problems, bird strikes, or ATC problems.

It is important to note that the majority of RTO accidents were not the result of an RTO initiated because of an engine failure. Full takeoff thrust from all engines was available. With normal takeoff thrust, the aircraft should easily reach a height of 150 feet over the end of the runway, and the pilot has the full length of the runway to stop the aircraft if an air turnback is required.

Making the Go/Stop decision starts long before V1. Early detection, good crew coordination, and quick reaction are the keys to a successful takeoff or stop.

Tail Strike

CAUTION: Early or rapid rotation may cause tail strike. Do not chase the Flight Director or rotate to an excessive attitude. If a tail strike is suspected, depressurize aircraft (time permitting). Structural damage can be aggravated by pressurization.

CAUTION: Always ensure selected flaps correspond to desired WDR setting, since improper setting of flaps and airspeed bugs significantly increases the incidence of tailstrikes.

Tail strike occurs when the lower aft fuselage or tail skid (as installed) contacts the runway during takeoff or landing. A significant factor that appears to be common is the lack of flight crew experience in the model being flown. Understanding the factors that contribute to a tail strike can reduce the possibility of a tail strike occurrence.

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Takeoff Risk Factors

Any one of the following takeoff risk factors may precede a tail strike:

Mistrimmed Stabilizer

This usually results from using erroneous takeoff data, e.g., the wrong weights, or an incorrect center of gravity (CG) or an incorrectly set stabilizer. The flight crew can prevent this type of error and correct the condition by challenging the reasonableness of the WDR numbers. Comparing the WDR numbers against past experience in the airplane can assist in approximating numbers that are reasonable.

Rotation at Improper Speed

This situation can result in a tail strike and is usually caused by early rotation due to some unusual situation, or rotation at too low an airspeed for the weight and/or flap setting.

Trimming during Rotation

Trimming the stabilizer during rotation may contribute to a tail strike. The pilot flying may easily lose the feel of the elevator while the trim is running which may result in an excessive rotation rate.

Excessive Rotation Rate

Flight crews operating an airplane model new to them, especially when transitioning from an airplane with unpowered flight controls to one with hydraulic assistance, are most vulnerable to using excessive rotation rate. The amount of control input required to achieve the proper rotation rate varies from one model to another. When transitioning to a new model, flight crews may not realize that it does not respond to pitch input in exactly the same way as their previous model.

Improper Use of the Flight Director

The flight director provides accurate pitch guidance only after the airplane is airborne. With the proper rotation rate, the airplane reaches 35 feet with the desired pitch attitude of about 20°. However, an aggressive rotation into the pitch bar at takeoff is not appropriate and can cause a tail strike.

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Initial Climb - All Engines

After liftoff, use the attitude indicator as the primary pitch reference. The flight director, in conjunction with indicated airspeed, and other flight instruments is used to maintain the proper vertical flight path. Pitch, airspeed, and airspeed trends must be crosschecked whether the flight director is used or not.

After liftoff, the flight director commands pitch to maintain an airspeed of V2 +10 knots until another pitch mode is engaged.

V2 + 10 knots is the optimum climb speed with takeoff flaps. It results in the maximum altitude gain in the shortest distance from takeoff. Acceleration to higher speeds reduces the altitude gain. If airspeed exceeds V2 + 10 knots during the initial climb, stop the acceleration by increasing pitch to a maximum of 20°, but do not attempt to reduce airspeed to V2 + 10. A speed slightly higher than V2 + 10 will not significantly affect the climb profile. Crosscheck indicated airspeed for proper initial climb speed.

Retract the landing gear after a positive rate of climb is indicated on the altimeter. Do not apply brakes after becoming airborne. Automatic wheel braking occurs during gear retraction. After gear and flaps are retracted, the PM should verify that the gear and flap indications are normal.

Minimum Fuel Operation for Takeoff

Verify flight plan MIN FUEL FOR T/O is onboard prior to beginning the takeoff roll. On very short flights this fuel quantity may not be enough to prevent forward fuel pressure low message from illuminating after takeoff.

Immediate Turn after Takeoff - All Engines

CAUTION: Preselecting a heading more than 180° from the runway heading and then pulling the HDG SEL knob will cause the autoflight system to command a turn in the shortest direction, which may be contrary to the ATC clearance.

Obstacle clearance, noise abatement, or departure procedures may require an immediate turn after takeoff. Initiate the turn at the appropriate altitude (normally at least 400 feet AFE) and limit bank angle to 15° maximum until maneuver speed for the takeoff configuration is attained. Once at or above the minimum maneuvering speed for the existing flap/slat configuration, set the bank angle limiter on the MCP to 25° or 30° and maintain at or above the minimum maneuvering speed to complete the turn. This may also require the use of FMS OVRD or a non-FMS speed mode to maintain the selected speed.

Note: A maximum bank angle of 30° is permitted at V2 + 20 knots with takeoff flaps.

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After completing the turn, and at or above acceleration height, accelerate and retract flaps while climbing.

Note: The possibility of an engine failure along the departure track must be considered. Special engine-out procedures, if available, are preferable to a takeoff weight reduction to ensure all obstacles are cleared.

Roll Modes

After takeoff and climb is stabilized, select NAV, or HDG SEL, on the MCP after passing 400 feet AFE. NAV (lateral guidance) outputs from the FMS are normally great circle courses between the waypoints making up the active route. However, when a procedure stored in the FMS database is entered into the active route, the FMS can supply commands to fly a constant heading, track, or follow a DME arc.

NAV engagement will occur if the cross track distance from the aircraft is 2.5 nm or less, or the aircraft is on an intercept heading with the active route and the FMS calculates a smooth intercept.

During NAV mode operations, commanded roll angles and roll limits do not consider the MCP bank angle limiter. Normally, FMS commanded turns are limited to 25° of bank. However, the bank angle limit is 15° if NAV is engaged, the slats are extended, and the airspeed is less than an FMS computed minimum speed.

If the departure procedure or route does not begin at the end of the runway, it may be necessary to use the HDG SEL mode at 400 feet AFE to intercept the desired track for NAV capture. When the departure procedure is not a part of the active flight plan, use HDG SEL or HDG HLD mode. When an immediate turn after takeoff is necessary, the desired heading may be preset before takeoff.

Navaids and appropriate radials required for use during the departure may be displayed on the navigation display using the FIX page feature and/or VOR/ADF. Use of the MAP declutter buttons on the EFIS mode selector panel provides additional information on the navigation display.

Note: During turns after takeoff, lateral flight director commands may lead to the aircraft flying outside the desired track. Closely monitor the cross track error on departure to keep the aircraft inside the RNAV navigational tolerance.

Pitch Modes

Normally, VNAV is engaged at 1,000 feet AFE. The use of VNAV is the preferred method of managing the FMS in the climb. This provides the VNAV profile and acceleration schedule compatible with the planned departure. If not using VNAV, select IAS and EPR LIM on the MCP, rotate pitch wheel to 250 knots and set speed command bug to 250 knots.

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Autopilot Engagement

The minimum altitude for autopilot engagement is 500 feet AGL.

The aircraft should be in trim, and the flight director commands should be satisfied before autopilot engagement. This prevents unwanted changes from the desired flight path during autopilot engagement.

Flap Retraction Schedule

Normally, 1,000 feet AFE is used as the acceleration height to initiate thrust reduction and flap retraction. The altitude selected for acceleration and flap retraction may be specified for each airport. Safety, obstruction clearance, aircraft performance, or noise abatement requirements are usually the determining factors.

At acceleration height, lower the pitch to approximately 10° and retract flaps at the Flap Retraction Speed from the Speed Book.

The 10° pitch attitude will allow the aircraft to rapidly accelerate to 250 knots while climbing. If the 10° pitch attitude generates a rate of climb significantly less than 1,000 fpm, the pilot should increase the pitch attitude to obtain a higher climb rate and accept the slower acceleration to clean speed. If the 10° pitch attitude generates a climb in excess of 1,000 fpm, maintain the 10° pitch and accept the added performance.

With airspeed increasing, retract the slats when reaching the Speed Book SLAT RET Speed. Limit bank angle to 15° when below maneuvering speed for the existing configuration.

Note: Do not move the FLAP TAKEOFF selector unless the FLAP/SLAT handle is in the UP RET position as the mechanism may cause binding/jamming of the FLAP/SLAT handle.

Takeoff Flap Retraction Speed Schedule

Configuration	Flap Retraction Speed
Flaps 1-13	V2 + 5 knots
Flaps 15-24	V2 + 15 knots

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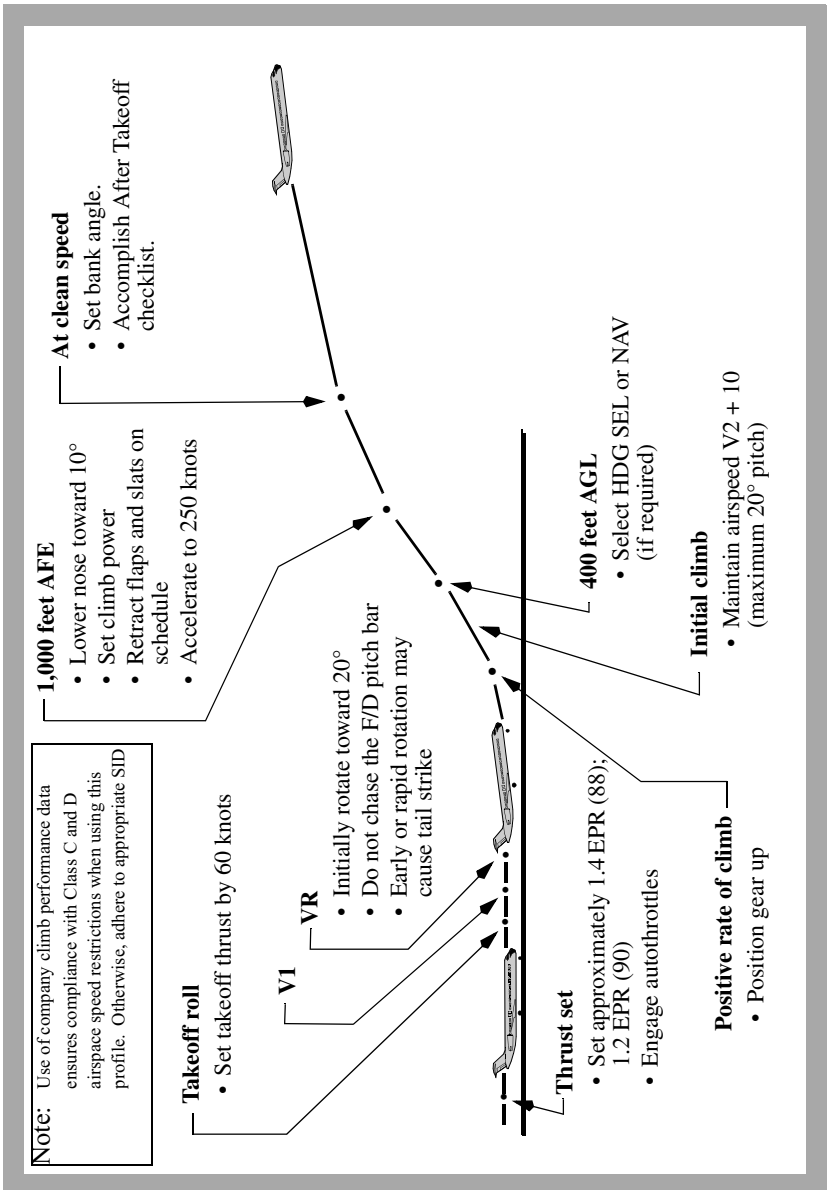
Normal Takeoff Profile (Distant/ICAO NADP 2)

The following profile satisfies typical vertical noise abatement requirements.



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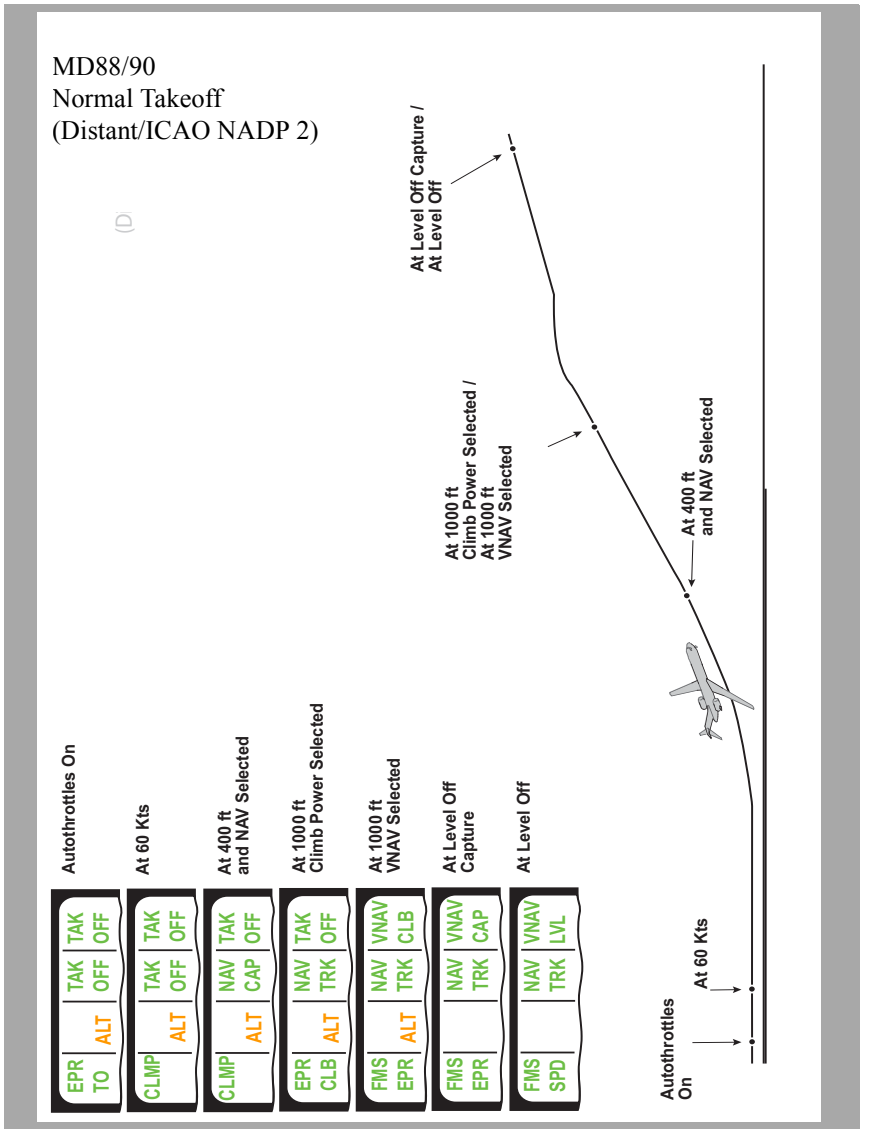
Normal Takeoff (Distant/ICAO NADP 2) FMA Progression



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Normal Takeoff (Distant/ICAO NADP 2)

The Normal Takeoff profile (Distant/ICAO NADP 2) is the normal takeoff procedure and is the default FMS profile. The Distant/ICAO NADP 2 reduces noise slightly for communities that are not within the immediate vicinity of the runway end.

- Take off using AWABS generated takeoff power and flaps setting.
- At 1,000 feet AFE, reduce thrust to climb power.
- Simultaneously (at 1,000 feet AFE) reduce rate of climb and accelerate.
- As the airplane accelerates, retract flaps on schedule.
- Accelerate to appropriate climb speed.

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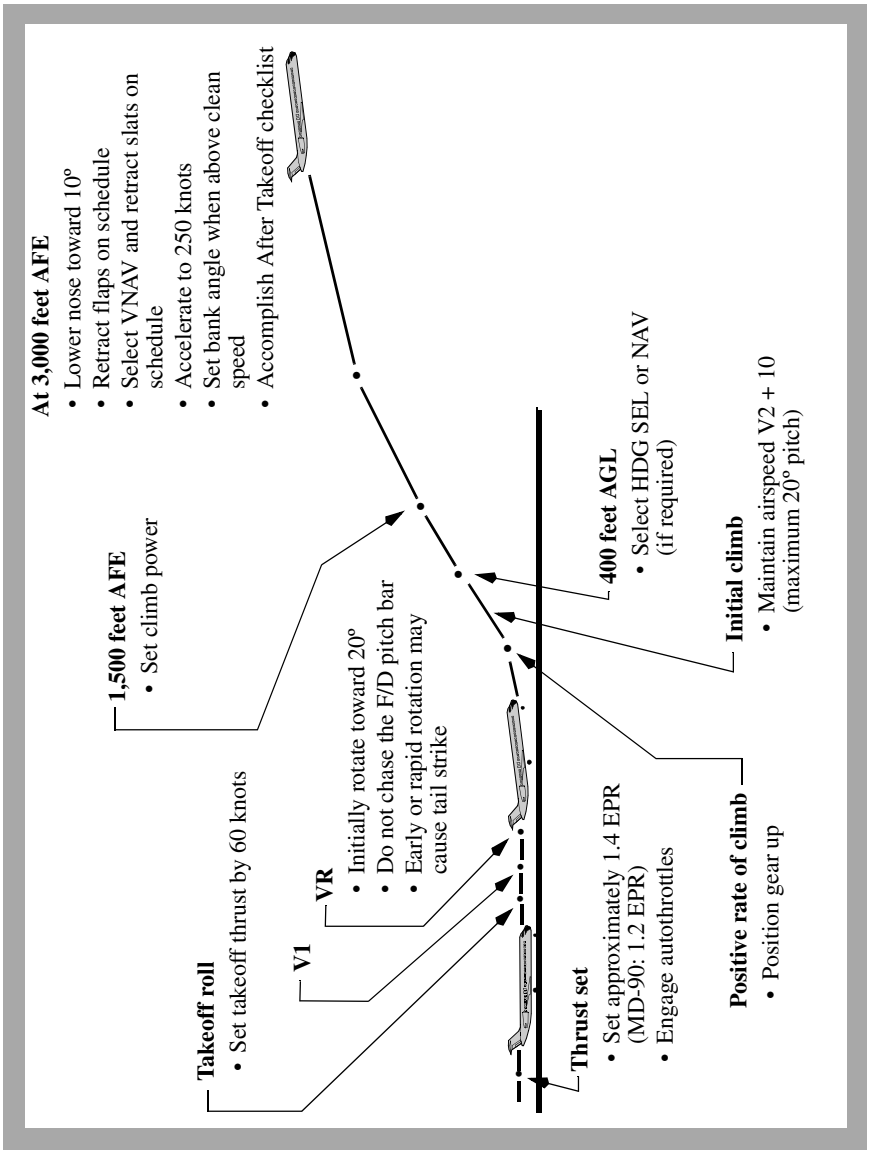
Special Takeoff Profile (Close-In/ICAO NADP 1)

The following profile satisfies noise abatement requirements for noise sensitive areas in close proximity to the departure end of an airport runway.



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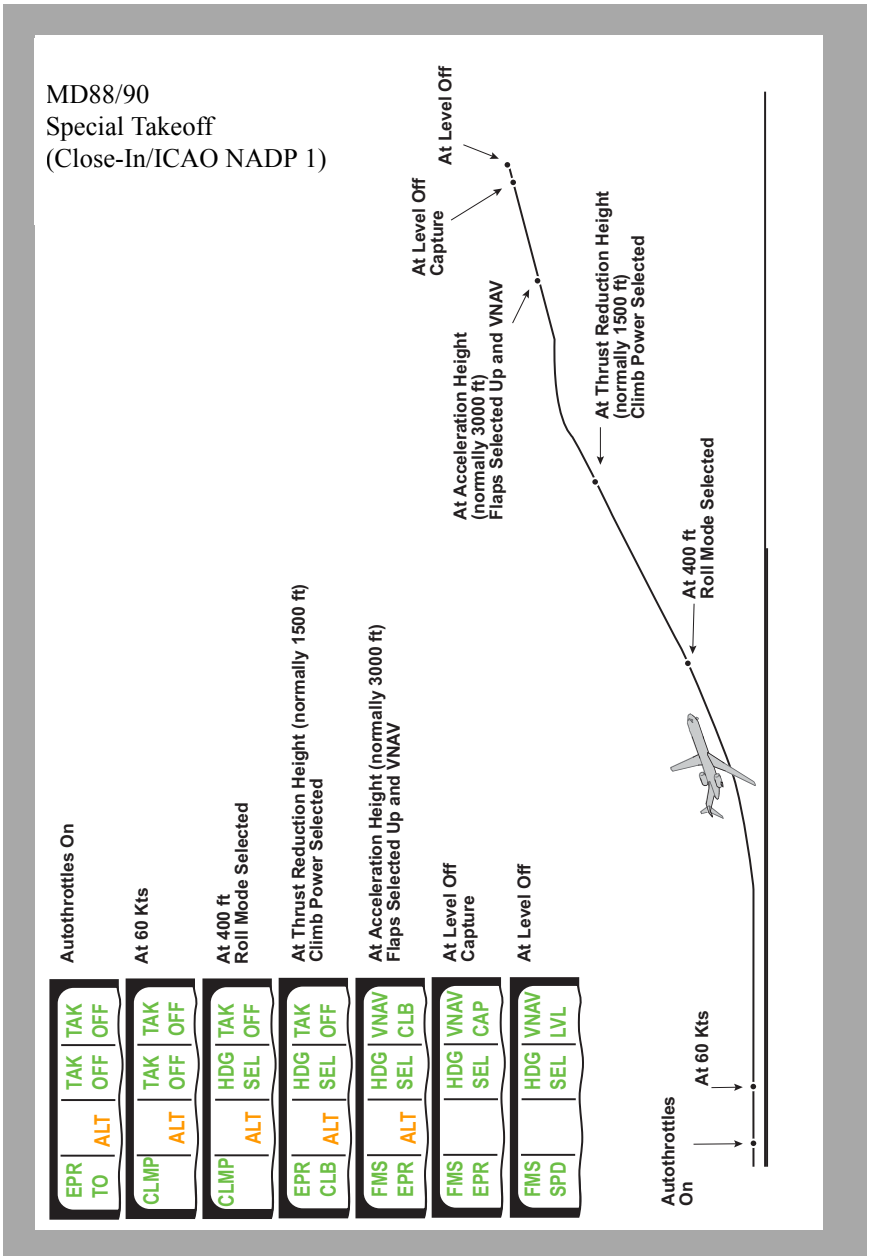
Special Takeoff Profile (Close-In/ICAO NADP 1) FMA Progression



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Special Takeoff (Close-In/ICAO NADP 1)

The Special Takeoff profile (Close-In/ICAO NADP 1) reduces noise for communities within the immediate vicinity of the runway end.

- Take off using AWABS generated takeoff power and flaps setting.
- At 1,500 feet AFE reduce thrust to climb power, maintain takeoff flaps.
- Continue (at 1,500 feet AFE) to fly commanded airspeed.
- At 3,000 feet AFE reduce rate of climb and accelerate.
- As the airplane accelerates, retract flaps on schedule.
- Accelerate to appropriate climb speed.

Note: AFDS will command appropriate pitch for acceleration segment.

Noise Abatement Takeoff

Regulatory agencies such as the FAA and ICAO have established standardized takeoff profiles so that an aircraft will use the same operating procedures throughout the world. Each operator develops specific procedures for flying Noise Abatement Departure Profiles (NADPs) that meet regulatory requirements. Airports are permitted to decide the appropriate NADP to use on each runway. Unless otherwise instructed, airlines will typically use the Distant/ICAO NADP 2.

Following flap retraction, maintain flaps up maneuver speed until the noise abatement profile is satisfied and the aircraft is clear of obstacles or above any minimum crossing altitude. This is normally achieved through the FMS speed restriction entered on the CLB page. It may also be accomplished using FMS OVRD.

Note: Specific local airport procedures should be followed.

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Takeoff - Engine Failure

Engine Failure Recognition

Prior to V1

One engine out controllability is excellent during takeoff roll and after liftoff. Minimum control speed in the air is below VR and VREF.

At or After V1

An engine failure at or after V1 initially affects yaw much like a crosswind effect. Vibration and noise from the affected engine may be apparent and the onset of the yaw may be rapid.

The aircraft heading is the best indicator of the correct rudder pedal input. To counter the thrust asymmetry due to an engine failure, stop the yaw with rudder. At V1 approximately 1/3 to 1/2 rudder pedal deflection is required to provide directional control with nosewheel still in contact with the runway. Under some conditions failure may not be immediately felt and should be identified or confirmed by engine instruments. Flying with lateral control wheel displacement or with excessive aileron trim causes spoilers to be raised.

Rotation and Liftoff - One Engine Inoperative

If an engine fails between V1 and liftoff, maintain directional control by smoothly applying rudder proportionate with thrust decay.The PF should maintain runway centerline or a line parallel to the runway centerline using rudder inputs. Anticipate the need for additional rudder as the nosewheel comes off the ground due to loss of rudder pedal steering.

With an engine inoperative, a smooth continuous rotation is also initiated at VR to a target pitch attitude of 12.5°. The rate of rotation with an engine inoperative is also slightly slower (1/2° per second less) than that for a normal takeoff. After liftoff adjust pitch attitude to maintain the desired speed of V2 to V2 +10. When the flight director pitch bar decreases from approximately 20° to the 12-15° range, transfer the pitch reference to the flight director and follow it to 1,000 feet AFE. Once the logic determines an engine failure has occurred, the fast slow indicator, when centered, can be used as a reference to maintain V2 to V2 +10.

If the engine failure occurs at or after liftoff apply rudder and aileron to control heading and keep the wings level. In flight, correct rudder input approximately centers the control wheel. To center the control wheel, rudder is required in the direction that the control wheel is displaced. This approximates a minimum drag configuration.

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Initial Climb - One Engine Inoperative

The initial climb attitude should be adjusted to maintain a minimum of V2 and a positive climb. Once a climb is established and flight sensing logic determines an engine failure occurred, the flight director will provide proper pitch guidance. Crosscheck indicated airspeed, vertical speed, and other flight instruments. The flight director commands a minimum of V2, or the existing speed up to a maximum of V2 + 10.

If the flight director is not used, attitude and indicated airspeed become the primary pitch references.

Retract the landing gear after a positive rate of climb is indicated on the altimeter. The initial climb attitude should be adjusted to maintain a minimum of V2. If an engine fails at an airspeed between V2 and V2 +10, climb at the airspeed at which the failure occurred. If engine failure occurs above V2 + 10, increase pitch to reduce airspeed to V2 + 10 and maintain V2 + 10 until reaching acceleration height.

The flight director roll mode commands wings level after liftoff until another roll mode is selected. If ground track is not consistent with desired flight path, use HDG SEL /NAV to achieve the desired track.

Indications of an engine fire, impending engine breakup, or approaching or exceeding engine limits should be dealt with as soon as possible. Accomplish the appropriate memory checklist items as soon as the aircraft is under control, the gear has been retracted, and a safe altitude (minimum 400 feet AGL or above) has been attained. Due to asymmetric thrust considerations, it is recommended that the PF retard the affected throttle after the PM confirms that the PF has identified the correct engine.Accomplish the non-normal checklist items as conditions permit. If an engine failure has occurred during initial climb, accomplish the appropriate checklist as conditions permit.

Immediate Turn after Takeoff - One Engine Inoperative

Obstacle clearance or departure procedures may require a special engine-out departure procedure. Refer to Airway Manual, Ops Specs, Departure / Missed Approach / Rejected Landing Priorities. If an immediate turn is required, initiate the turn at the appropriate altitude (normally at least 400 feet AFE).

Note: Limit bank angle to 15° until V2 + 20 knots. Bank angles up to 30° are permitted at V2 + 20 knots with takeoff flaps.

After completing the turn, and at or above acceleration height, accelerate to V2 + 20.

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Autopilot Engagement - One Engine Inoperative

After establishing the climb above 1,000 feet AFE with correct rudder trim input, the autopilot may be engaged.

Acceleration Height - One Engine Inoperative

At 1,000 feet AFE, or altitude specified in company pages, select ALT HOLD and follow Flight Director pitch bar to level off. Maintain current configuration with flaps and slats extended. Verify the speed command bug is set to V2 + 20 and accelerate to at least minimum maneuver speed for existing flaps (V2 + 20 is the minimum maneuvering speed for all T/O flap settings).

At Maneuver Speed (Minimum):

- Select IAS
- Select MCT
- Select EPR LIM
- Set bank angle to 25°.

Initiate a climb at minimum maneuver speed to pattern or vector altitude.

After establishing the climb, and in trim, engage the autopilot if desired. Adjust rudder trim to level the control wheel. Use white index markings on other pilot's control wheel as a reference.

Accomplish appropriate After Takeoff checklist items and non-normal checklist items, as necessary. It is not necessary to complete the After Takeoff checklist in its entirety.

- Confirm gear is up
- Select ignition OFF
- Disarm spoilers
- Select autobrakes OFF.

If the decision is made to remain in the pattern for a return to the departure airport, consider maintaining takeoff flap setting while maneuvering to land.

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Diverting to an Alternate - One Engine Inoperative

When the aircraft is established at V2+20 with takeoff flaps set, a decision to return to the departure airport or divert to an alternate can be made. If diverting to an alternate, target climb speed will be Slat Retract (SR) + 20 (speed book) in the clean configuration. SR + 20 is not a maneuvering speed. It is recommended that the initial turn toward the divert airfield be completed at a maneuvering speed and prior to clean up. Once on course to the alternate, accelerate while retracting the flaps and slats on schedule. Establish an IAS climb at SR +20 and set the speed command bug to single engine cruise speed minimum. Use HDG SEL mode at 15° of bank until a maneuvering speed is reached. Use caution when using NAV with the slats retracted; it may result in bank angles greater than 15°. The FMS provides an equivalent profile after selecting ENG OUT on the CLB page. VNAV can then be used if the autothrottles are re-engaged during the accomplishment of a non-normal checklist. Climb at the FMS engine-out climb speed until reaching single-engine cruise altitude then accelerate to ENG OUT cruise speed or higher after evaluating fuel remaining and distance to the alternate airport. Consult the FMS/ODM to determine best single-engine cruise speed.

Note: Adjust the rudder trim as necessary throughout the diversion and closely monitor fuel distribution to avoid an imbalance condition.

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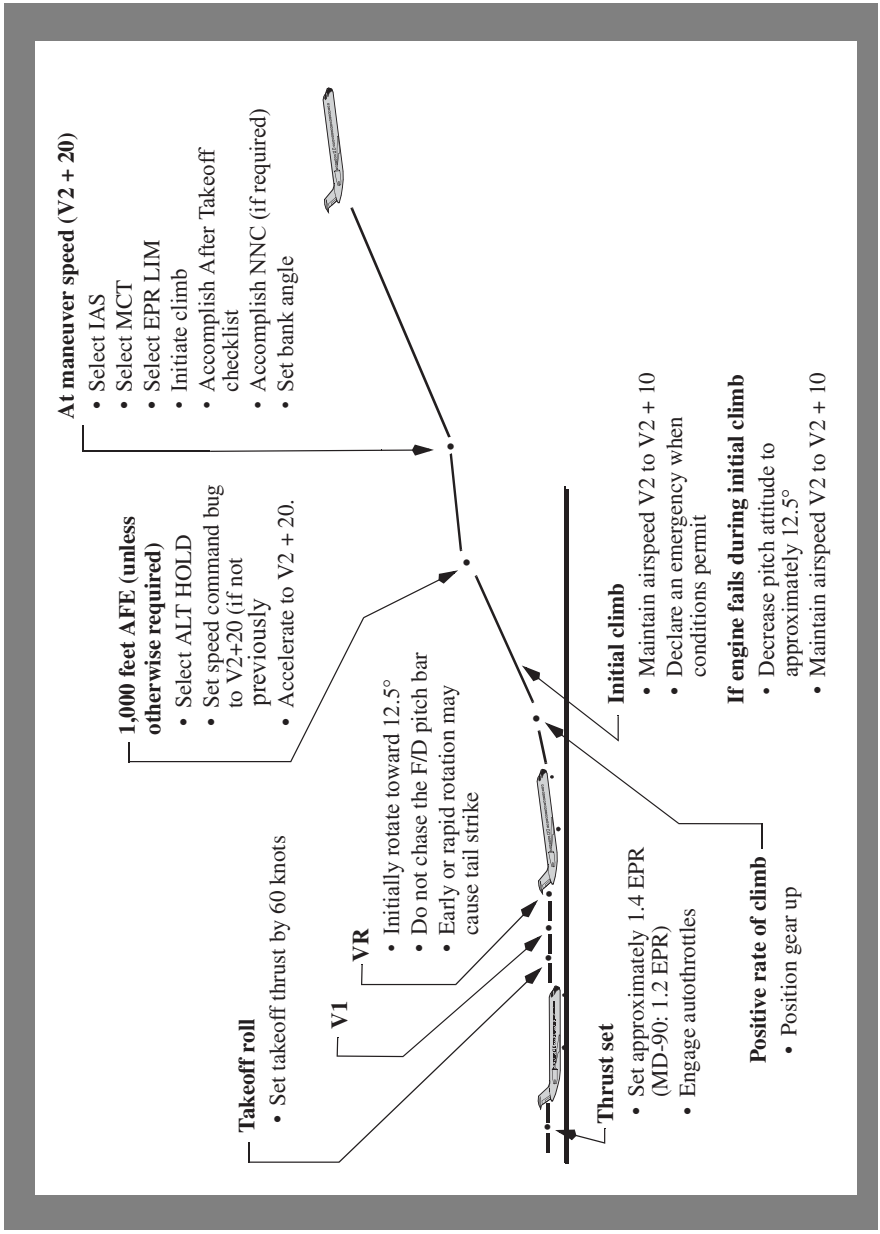
Takeoff Profile - Engine Failure



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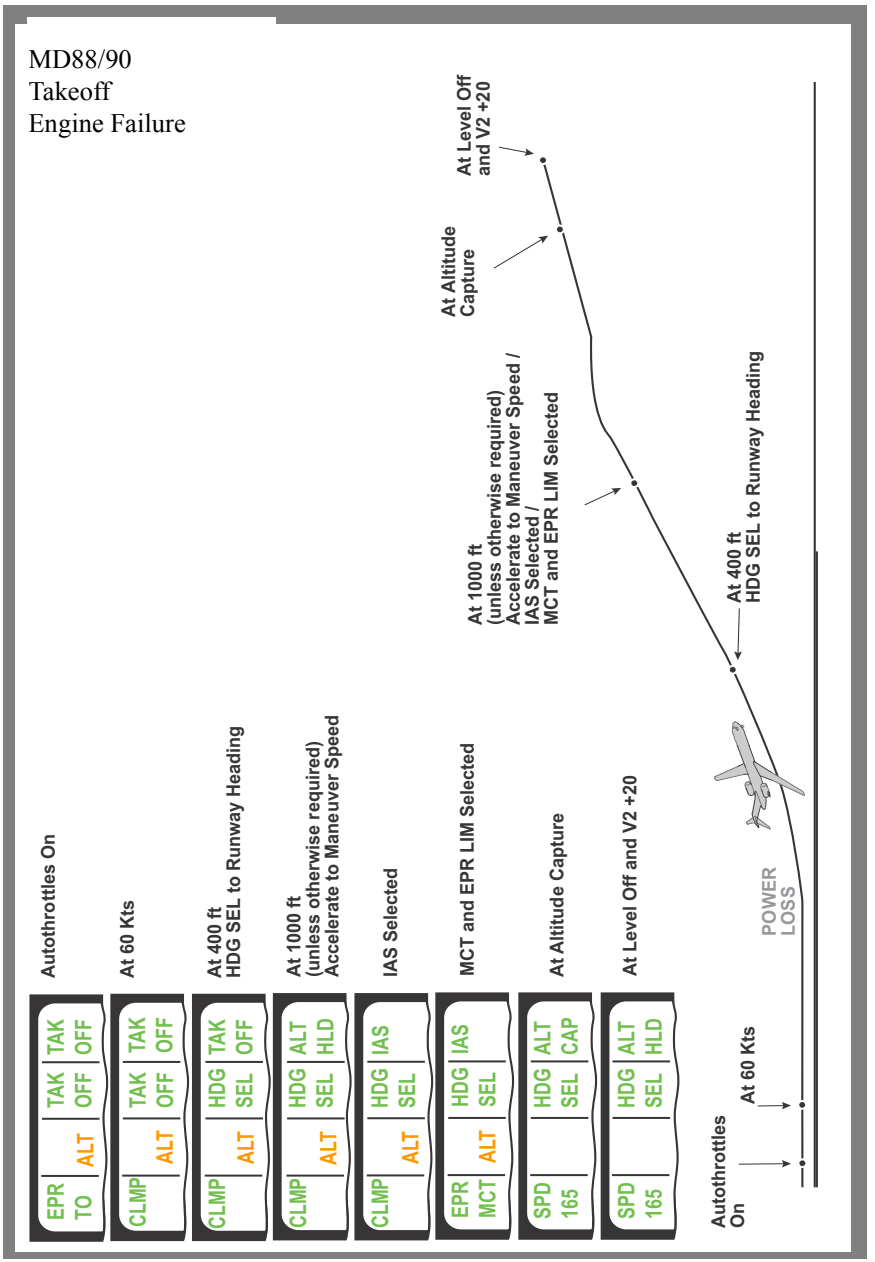
Engine Failure FMA Progression



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Engine Failure after V1

PF	PM
at approximately 1.4 EPR…	as indicated
"AUTOTHROTTLES ON"	"EPR XX"
	"CLAMP, 80 KNOTS, THRUST NORMAL"
	"V1, ENGINE FAILURE, ROTATE, POSITIVE RATE"
"GEAR UP"	
recommended technique above 400 feet AFE…	
Declare an emergency. Comply with Airway Manual, Ops Specs, Departure / Missed Approach / Rejected Landing Priorities	
"SET SPEED COMMAND BUG TO V2 + 20"	
at 1000 feet AFE…	
"ALTITUDE HOLD, SET SPEED COMMAND BUG TO V2 + 20" (if not already set)	
at V2 + 20...	
"IAS, MCT, EPR LIMIT, BANK ANGLE 25, AFTER TAKEOFF CHECKLIST, ENGINE FAILURE CHECKLIST"	
recommended technique…	
"AUTOPILOT ON"	

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Engine Failure During an ATM Takeoff

Since the ATM takeoff must still comply with all regulatory takeoff performance requirements, it is not necessary to increase thrust beyond the reduced level on the operating engine in the event of an engine failure. However, if more thrust is needed during an ATM takeoff, thrust on the operating engine may be increased to normal takeoff thrust by manually advancing the throttle. This is because the takeoff speeds consider VMCG and VMCA at the normal takeoff thrust.

Increasing thrust on the operating engine to full rated takeoff thrust provides additional performance margin. This additional performance margin is not a requirement for the reduced thrust takeoff and its use is at the discretion of the flight crew.

If engine fails above 400 feet AGL the autothrottles will unclamp, the TRP will change to GA, and the throttles will advance to go-around power.

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Climb, Cruise, Descent and Holding — Chapter 4
Table of Contents — Section TOC

Climb 4.1
Climb Modes 4.1
Climb Constraints 4.2
Low Altitude Level Off 4.2
Transition to Climb 4.3
Climb Speed Determination 4.3
Engine Icing During Climb 4.4
Economy Climb 4.4
Economy Climb Schedule - FMS Data Unavailable 4.4
Maximum Angle Climb 4.4
Engine Inoperative Climb 4.5

Cruise 4.5
Cruise Speed Definitions 4.5
Cruise Speed Determination 4.6
Maximum Altitude 4.7
Optimum Altitude 4.8
Step Climb 4.9
FMS Wind Entries 4.10
Cruise Performance Economy 4.10
Engine Inoperative Cruise/Driftdown 4.11
High Altitude Performance 4.12
ETOPS 4.14

Descent 4.14
Descent Planning 4.14
Descent Speed Determination 4.17
Descent Path 4.17
Descent Constraints 4.17

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FMS Override 4.18
Early Descent from Cruise. 4.18
Approaching Top-of-Descent (TOD) 4.20
VNAV Descent From Above Path. 4.20
Other Modes of Descent 4.20
Descent Rates. 4.21
Speedbrakes 4.22
Flaps and Landing Gear. 4.22
Air Foil Icing During Descent 4.23
Throttle Technique. 4.23

Holding. 4.24
Holding Airspeeds 4.24
Holding Airspeeds Not Available from the FMS 4.25
Holding Pattern Exit 4.25

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Climb

(90) Some aircraft have reduced thrust climb capability (CLB1, CLB2), however Delta Air Lines' policy does not currently allow reduced thrust climb.

Reduced thrust climb may also be automatically selected by the FMS depending upon the amount of thrust reduction made for takeoff by either the fixed derate or assumed temperature method.

Note: Use of reduced thrust for climb increases total trip fuel.

Climb Modes

There are three climb modes available:

VNAV

Flight director pitch guidance commands the pitch attitude to maintain speed. While in VNAV, speed changes are accomplished by entering a new speed on the CLB page or using FMS OVRD. Thrust is fixed as indicated by FMS EPR on the FMA.

IAS/MACH

CAUTION: Selecting VNAV while accelerating in a IAS climb mode at slightly below FMS climb speed can cause an over speed warning to occur because of slow pitch rate of the FMS in the VNAV climb mode.

CAUTION: Do not actuate the pitch wheel when nearing altitude capture. This will disable the ALT CAP mode and result in an altitude deviation. Confirm all MCP changes are annunciated on the FMA.

CAUTION: Changing the barometric altimeter setting while in the ALT CAP mode causes the autopilot to level the airplane above or below the selected altitude. However, resetting the barometric altimeter while in VNAV CAP will not interfere with level off at selected altitude.

When VNAV use is not desired, IAS/MACH mode is normally used for large changes in altitude (more than 2,000 feet). It will provide a rate of climb based upon thrust setting and will command a pitch attitude to acquire and maintain the selected IAS/MACH.

- Select a higher altitude in the MCP altitude window.
- Start the aircraft climbing by actuating the pitch wheel. This will place the autopilot in the vertical speed mode.
- Select IAS/MACH on the MCP.

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- Rotate the pitch wheel to the desired airspeed or mach.
- Select EPR limit to achieve the appropriate climb power setting.

VERT SPD

CAUTION: In VERT SPD, no stall or overspeed protection is provided. Therefore, VERT SPD is not normally used to climb.

Vertical Speed

When VNAV use is not desired, vertical speed (V/S) mode is normally used for small changes in altitude (approximately 2,000 feet or less) and for non-precision approaches. It will provide a constant rate climb.

- Select a higher altitude in the MCP altitude window.
- Push the vertical speed button (this is only necessary if operating in the IAS/Mach mode).
- Rotate the pitch control wheel to the desired rate of climb.

Climb Constraints

Climb constraints may be automatically entered in the route when selecting a procedure, or manually entered through MCDU entry.

For climbs in pitch modes other than VNAV, the MCP altitude must be set at the next altitude constraint.

When relieved of constraints by ATC, use of VNAV with MCP altitude intervention is recommended. Selecting CLB DIR will remove all altitude constraints between the current aircraft altitude and the altitude set in the MCP. Waypoint constraints can also be manually deleted from the LEGS page.

Low Altitude Level Off

Low Altitude Level Off Without VNAV

If ALT CAP occurs prior to selection of CLB thrust, the TRP remains in a takeoff mode, the autothrottles will remain clamped and no overspeed protection is available. If this occurs:

- Select CLB thrust. This will restore the ATS overspeed protection logic.
- Set the command speed bug to 250 knots.
- Press SPD SEL on the MCP, or
- Disconnect the autothrottles and retard the throttles manually so as not to exceed limit speeds.

Low Altitude Level Off With VNAV

When taking off with an initial level off below 2,500 feet AFE and using VNAV, no special procedure is required.

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High Takeoff Thrust - Low Gross Weight

When accomplishing a low altitude level off following a takeoff using high takeoff thrust and at a low gross weight, the crew should consider the following factors:

- Altitude capture can occur just after liftoff due to the proximity of the level-off altitude and the high climb rate of the aircraft
- The DFGS will limit F/D and autopilot pitch commands for passenger comfort
- There may not be enough altitude below the intended level-off altitude to complete the normal capture profile and an overshoot may occur unless crew action is taken.

To prevent an altitude and/or airspeed overshoot, the crew should consider doing one or more of the following:

- Use reduced thrust for takeoff at low weights whenever possible
- Disengage the autopilot and complete the level off manually if there is a possibility of an overshoot
- Use manual thrust control as needed to manage speed and prevent flap overspeeds.

Transition to Climb

Maintain flaps up maneuver speed until clear of obstacles or above minimum crossing altitudes. If there are no altitude or airspeed restrictions, accelerate to the desired climb speed schedule.

Climb Speed Determination

Enroute climb speed is automatically computed by the FMS and displayed on the CLB and PROGRESS pages. It is also displayed as command speed when VNAV is engaged. Below the speed transition altitude the FMS targets the transition speed limit stored in the navigation database for the departure airport (typically 250 knots below 10,000 feet MSL), (90) and/or flaps up maneuvering speed, whichever is higher. The FMS applies waypoint-related speed restrictions displayed on the LEGS pages, and altitude-related speed restrictions displayed on the CLB page.

The FMS provides optimum climb speed modes for economy (ECON) operation and engine out (ENG OUT) operation. These optimum speeds can be changed before or during the climb. Reference speeds are also provided for maximum angle climb (MAX ANGLE) operation.

The ECON climb speed is a constant speed/constant Mach schedule optimized to obtain the minimum aircraft operating cost. The constant Mach value is set equal to the economy cruise Mach calculated for the cruise altitude entered in the FMS.

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For very low cruise altitudes the economy climb speed is increased above normal values to match the economy cruise speed at the entered cruise altitude. For ECON climb, the speed is a function of gross weight (predicted weight at top of climb), predicted top of climb wind, predicted top of climb temperature deviation from ISA, and cost index.

Engine Icing During Climb

CAUTION: The engine anti-icing system should be ON whenever icing conditions exist or are anticipated. Failure to follow the recommended anti-ice procedures can result in airspeed decay, engine stall, overtemperature, or engine damage.
Refer to Vol. 1, SP.16.

Engine icing may form when not expected and may occur when there is no evidence of icing on the wiper bolt or other parts of the aircraft. Once ice starts to form, accumulation can build very rapidly. Although one bank of clouds may not cause icing, another bank, which is similar, may cause icing.

Economy Climb

The normal economy climb speed schedule of the FMS minimizes trip cost. It varies with gross weight and is influenced by cost index. The FMS generates a fixed speed schedule as a function of cost index and weight.

Economy climb speed normally exceeds 250 knots for all gross weights. FMS climb speed is limited to 250 knots below 10,000 feet (FAA Airspace), or a lower waypoint speed restriction, if entered. If the use of a higher speed below 10,000 feet is allowed, ECON speed provides additional cost savings.

Economy Climb Schedule - FMS Data Unavailable

- Below 10,000 feet - 250 knots /Clean speed, whichever is higher
- Above 10,000 feet - Climb at 310 knots until transitioning to flight planned cruise Mach (approximately 27,000 feet). Transition to flight planned cruise Mach at this time by reselecting the IAS/MACH select button on the MCP.

Maximum Angle Climb

Maximum angle climb speed is normally used for obstacle clearance, minimum crossing altitude, or to reach a specified altitude in a minimum distance. It varies with gross weight and provides approximately the same climb gradient as flaps up maneuver speed.

Note: The FMS provides maximum angle climb speeds.

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Engine Inoperative Climb

The recommended engine inoperative climb speed approximates the speed for maximum climb gradient and varies with gross weight and altitude. After flap and slat retraction and all obstructions are cleared, on the CLB page, select ENG OUT. This displays the ENG OUT CLB page which provides VNAV commands to climb at engine-out climb speed to cruise altitude, or maximum engine-out altitude, whichever is lower. If the aircraft is currently above maximum engine-out altitude, driftdown information is available. Upon reaching level-off altitude, the command speed changes to engine out LRC. Leave thrust set at maximum continuous thrust until airspeed increases to the commanded value.

If a thrust loss occurs at other than takeoff thrust, set maximum continuous thrust (MCT) on the operative engine and adjust the pitch to maintain airspeed.

Leave thrust set at maximum continuous thrust until airspeed increases to the commanded value.

Note: If computed climb speeds are not available, use SLAT RET speed +20 knots and maximum continuous thrust.

SLAT RET+20 and the FMS ENG OUT CLIMB speed are below clean maneuvering speed. When clean, at the engine-out climb speed use HDG SEL with the Bank Angle Limit to 15° until on course to the destination. Selecting NAV while below maneuvering may result in bank angles greater than 15°.

Cruise

This section provides general guidance for the cruise portion of the flight for maximum passenger comfort and economy.

Cruise Speed Definitions

Maximum Range Cruise (MRC) (Cost Index zero)

- Based on aircraft weight, altitude, and OAT
- Provides theoretical maximum nautical air miles per pound of fuel burned
- Unstable speed results in autothrottle hunting, reducing efficiency.

Long Range Cruise (LRC)

- Based on aircraft weight, altitude, and OAT
- Provides 99% of the fuel mileage of MRC
- Provides a stable speed and reduces fuel costs with reduced flight times compared to fixed Mach.

ECON (dependent upon the Cost Index entered)

- Allows operators a custom ratio of hourly to fuel costs
- Based on aircraft weight, flight level, OAT, and actual winds
- Varies speed command as wind field changes

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- Provides minimum cost operation for the selected cost index
  - Are optimized for flight between M0.74 and M0.78
  - Slower speeds increase flight times with minimal reduction in fuel burn
  - Faster speeds result in rapidly increasing burns with reducing time benefit
- ECON flight is more cost-efficient than fixed Mach or LRC.

Cruise Speed Determination

Cruise speed is automatically computed by the FMS and displayed on the CRZ and PROGRESS pages. It is also displayed by the command speedbug when VNAV is engaged. The default cruise speed mode is economy (ECON) cruise. The pilot can also select long range cruise (LRC), engine-out modes, or overwrite fixed Mach values on the CRZ page target speed line. A manually entered Mach or indicated airspeed on the CRZ page is automatically propagated to the DES page. This prevents sudden speed changes at top of descent (TOD).

If required to cruise below your flight planned altitude, insert the new flight level in the CRZ page and fly the ECON speed for the new (lower) cruise altitude.

Headwinds increase the ECON CRZ speed. Tailwinds decrease ECON CRZ speed, but not below the zero wind maximum range cruise airspeed.

Cost Index

Performance data requires entry of the Cost Index and is the basis for economy speed (ECON). ECON is a speed schedule calculated to minimize operating cost during CLIMB, CRUISE, and DESCENT.

A low cost index causes a lower cruise speed. A cost index of zero ignores the cost of time resulting in maximum range cruise and a minimum fuel speed schedule. A low cost index may be used when fuel costs are high compared to operating costs. A cost index of 999 calls for maximum flight envelope speeds resulting in a minimum time speed schedule.

The flight plan may indicate Cost Index changes while enroute. The FMS allows Cost index modifications until within ten miles of the top of descent.

If for any reason the Cost Index modification changes either the indicated airspeed by more than 10 knots or 0.02 Mach or true airspeed by more than 5% or 10 knots from the planned Mach Number/TAS, inform the appropriate controlling agency.

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Maximum Altitude

Maximum altitude (MAX) is the highest altitude at which the aircraft can be operated. It is determined by these basic characteristics, which are unique to each aircraft model. The FMS-predicted maximum altitude is the lowest of:

- Maximum certified altitude - the altitude determined during certification considering structural limit (limits on the fuselage), rapid descent capability, or other factors determined by the certifying authority. The maximum certified altitude may not be exceeded.
- Thrust limited altitude - the altitude at which sufficient thrust is available to provide a specific minimum rate of climb. Refer to the Long Range Cruise Maximum Operating Altitude tables in the ODM. Depending on the thrust rating of the engines, the thrust limited altitude may be above or below the maneuver altitude capability.
- Buffet or maneuver limited altitude - the altitude at which a specific maneuver margin exists prior to buffet onset (minimum 0.25g for FAA). These specific margins provide 33° of bank angle protection to buffet.

The minimum maneuver speed displayed on the Speed Book does not guarantee the ability to maintain level flight at that speed. Decelerating the aircraft to the Speed Book clean speed may create a situation where it is impossible to maintain speed and/or altitude because as speed decreases aircraft drag may exceed available thrust, especially while turning. Flight crews intending to operate at or near the maximum operation altitude should be familiar with the performance characteristics of the aircraft in these conditions.

Note: To get the most accurate altitude limits from the FMS, ensure that the FMS PERF INIT fuel matches the fuel quantity.

When at or near the FMS optimum altitude, it is possible for NAV inputs to exceed the capability of the aircraft. This could result in loss of altitude or airspeed. Limit bank angle to 15° if operationally feasible.
When operating at or near maximum altitude, fly at least 10 knots above the Speed Book clean speed and consider using bank angles of 15° or less. If speed drops below the Speed Book clean speed, immediately increase speed by doing one or more of the following:

- Reduce angle of bank
- Increase thrust up to maximum continuous
- Descend.

Turbulence at or near maximum altitude can momentarily increase the aircraft's angle-of-attack and activate the stick shaker. When flying at speeds near the Speed Book clean speed, any maneuvering increases the load factor and further reduces the margin to buffet onset and stick shaker.

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FMS fuel predictions are not available above the FMS optimum altitude and are not displayed on the MCDU. VNAV is not available above FMS optimum altitude. Fuel burn at or above maximum altitude increases. Flight above this altitude is not recommended.

Optimum Altitude

CAUTION: Operating above the FMS calculated optimum cruise altitude can result in airspeed decay and eventual stall. Do not input any number less than the actual zero fuel weight or fuel on-board to obtain a higher optimum altitude.

Optimum altitude is the cruise altitude in still air for minimum cost when operating in the ECON mode, and for minimum fuel burn when in the LRC or pilot-selected speed modes. Optimum altitude does not consider the effects of temperature deviations from standard day or cruise winds at altitude.

Because optimum altitude targets minimum cost when using cost index, and minimum fuel burn for all other modes, it can be a different altitude at the same cruise Mach, depending on whether the cruise Mach is based on cost index or is manually entered as a selected speed. However, in either situation, optimum altitude continues to increase as weight decreases during the flight.

For shorter trips, optimum altitude as defined above may not be achievable since the top of descent (TOD) point occurs prior to completing the climb to optimum altitude.

Cruise altitude, as defined on the FMS PERF INIT page, further constrains optimum altitude by reducing the altitude for short trips until minimum cruise segment time is satisfied. This cruise time is typically one minute, but is selectable in the FMS by maintenance action. For short trips, operation at the cruise altitude results in the minimum fuel/cost while also satisfying the minimum cruise time requirement.

The selected cruise altitude should normally be as close to optimum as possible. Optimum altitude is the altitude that gives the minimum trip cost for a given trip length, cost index, and gross weight, without consideration of cruise winds. It provides adequate or better buffet margin. As deviation from optimum cruise altitude increases still air performance economy deteriorates.

On aircraft with higher thrust engines, the altitude selection is most likely limited by maneuver margin to initial buffet. Projected temperature and turbulence conditions along the route of flight should be reviewed when requesting/accepting initial cruise altitude as well as subsequent step climbs.

Flight crews have two sources of flight information available, the FPS flight plan and the FMS.

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Flight Planning Data:

- Purpose is to assure the captain and the dispatcher that the flight can be operated safely.
- Is calculated prior to departure.
- Uses forecast weights, winds, and temperatures available at dispatch.
- Is intentionally calculated so that normal ATC restrictions, weather, turbulence, etc., don't immediately result in a divert.

FMS Flight Operating Data:

- Provides guidance on how to operate the flight most efficiently, based on input of updated forecast conditions and actual weight.
- Is calculated in real time, using actual weights, winds, and temperatures as well as input of updated forecast conditions.
- Selects the altitude and cruise Mach to provide the maximum nautical ground miles per pound of fuel burned or best ECON speed and flight level, depending on FMS mode.
- If followed accurately can result in significantly less fuel burn than the flight plan predicts.

Step Climb

90

CAUTION: If you do not enter zero (0) in the Step Size field for a flight during which no step climbs are planned the FMS will base fuel computations at destination on the assumption that step climbs were made at the optimum calculated points.

Step altitudes can be planned at waypoints or they can be optimum step points calculated by the FMS. Optimum step points are a function of the route length, flight conditions, speed mode, present aircraft altitude, STEP TO altitude (or adjacent STEP TO altitudes), and gross weight. The FMS-computed step point provides for minimum trip cost for the flight, including allowances for climb fuel. Initiate a cruise climb to the new altitude as close as practicable to the step climb point, if conditions are favorable (e.g., turbulence, winds, use of engine/airfoil anti-ice).

Fuel for Enroute Climb

The additional fuel required for a 4,000 foot enroute climb varies from 500 to 1,000 pounds depending on the aircraft gross weight, initial altitude, air temperature, and climb speed. The fuel increment is largest for high gross weights and low initial altitudes. Additional fuel burn is offset by fuel savings in the descent. It is usually beneficial to climb to a higher altitude if recommended by the FMS or the flight plan, provided the wind information used is reliable.

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FMS Wind Entries

Wind values should be uploaded or entered into the FMS for all cruise segment waypoints during preflight. If time limitations do not permit the completion of wind FMS entries during the preflight, enter as many wind values as feasible. The remaining entries can be completed as workload permits.

(90)
The temperature must be entered at cruise altitude at each way point.

Wind values propagate along the route; therefore, enter new wind values for subsequent waypoints only when a difference exceeding 10 knots exists from the previous waypoint.

Note: The FMS-generated OPT cruise altitudes are the primary reference for altitude capability. However, the FMS altitudes do not forecast or consider Engine or Airfoil Anti-Ice ON during the climb or sustained cruise. At high gross weights or high ISA deviations the use of engine bleeds, especially during turbulence or maneuvering (e.g., holding), may limit available thrust and affect maximum altitude capability. If there is any question about cruise altitude capability or if FMS is inoperative, refer to the Maximum Recommended Initial Cruise Altitude chart in the ODM.

Cruise Performance Economy

The flight plan fuel burn from departure to destination is based on certain assumed conditions. These include takeoff gross weight, cruise altitude, route of flight, temperature, enroute winds, and cruise speed.

Actual fuel burn should be compared to the flight plan fuel burn throughout the flight.

The planned fuel burn can increase due to:

- Temperature above planned
- A lower cruise altitude than planned
- Speed faster than planned or appreciably slower than long range cruise speed when long range cruise was planned
- Stronger headwind component
- Fuel imbalance
- Improperly trimmed aircraft
- Excessive throttle adjustments.

Cruise fuel penalties can be approximated using the following guidance:

- ISA + 10° C: 1% increase in trip fuel
- 2,000 feet below optimum altitude: 1% to 2% increase in trip fuel
- 4,000 feet below optimum altitude: 4% to 5% increase in trip fuel
- 8,000 feet below optimum altitude: 12% to 14% increase in trip fuel

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- cruise speed 0.01M above LRC: 1% to 2% increase in trip fuel.

For cruise within 2,000 feet of optimum, long range cruise speed can be approximated by using 0.76M. Long range cruise also provides the best buffet margin at all cruise altitudes.

Note: If a discrepancy is discovered between actual fuel burn and flight plan fuel burn that cannot be explained by one of the items above, a fuel leak should be considered. Accomplish the applicable non-normal checklist.

Engine Inoperative Cruise/Driftdown

If an engine failure occurs during cruise apply rudder and trim to level the control wheel. This allows the autopilot to remain engaged. The autothrottle remains active with one engine inoperative.

CAUTION: The MCP altitude must be reset to a lower altitude in order for the FMS to start a driftdown. A stall may result if the MCP altitude is not reset.

If an engine failure occurs while at cruise altitude, it may be necessary to descend. On the FMS CRZ page, select the ENG OUT prompt. This displays ENG OUT CRZ and the FMS calculates engine-out target speed and maximum engine out altitude at the current gross weight. The fields are updated as fuel is burned.

When the Engine Out (E/O) mode is executed in cruise, and the aircraft is above the maximum E/O altitude, thrust will automatically advance to the EPR limit, then the following messages will appear on the MCDU:

- CHECK ALT TGT and
- SELECT MCT.

Set the EO CRZ ALT/D/D ALT or lower in the MCP altitude window and select MCT on the TRP. The aircraft will slow to engine-out speed then begin to drift down. If the engine-out target airspeed and maximum continuous thrust (MCT) are maintained, the airplane levels off above the original drift down altitude due to fuel burn in the descent.

After level off at the target altitude, maintain MCT and allow the airplane to accelerate to the single engine long range cruise speed. Entering the new cruise altitude and airspeed on the ENG OUT CRZ page updates the ETAs and Top of Descent predictions.

Driftdown Without VNAV

- Select MCT on the TRP.
- Reset MCP altitude.
- Decelerate to driftdown speed.
- Descend using Vertical Speed or IAS mode.
- After level-off, accelerate to E/O LRC.

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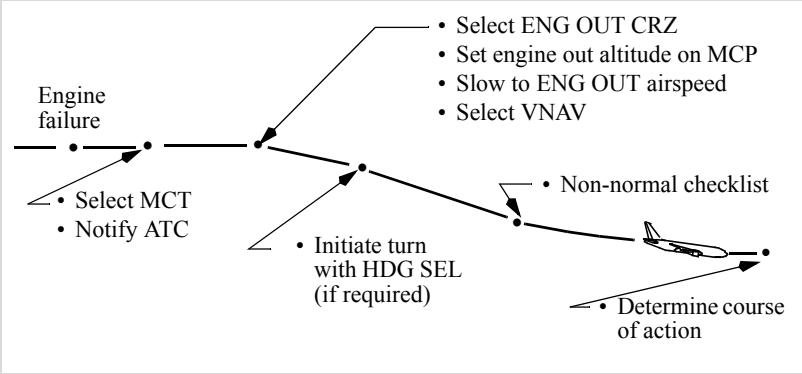

Note: If the aircraft is at or below maximum ENG OUT altitude when an engine becomes inoperative, select the ENG OUT CRZ page.

High Altitude Performance

Mach buffet and Mach tuck are associated with the formation of shock waves on the airfoil during transonic flight. Small, weak shock waves are formed on the wing at Mach 0.75. Although shock waves form much earlier, noticeable buffeting does not occur on the MD-88/90 until approaching MMO. At this Mach number, shock waves become quite large and strong, and move rapidly fore and aft on the wing, causing a gentle high frequency buffet.

Pressure distributions are affected when these shock waves occur, and this in turn affects the aircraft's lift, drag and pitching characteristics. Mach tuck will become noticeable at Mach 0.80; and, the pull force required to maintain level flight increases linearly up to Mach 0.85, then remains constant. It is for this reason that Mach trim compensation is needed above Mach 0.80.

Note: Maximum airspeed with malfunctioning or inoperative Mach Trim Compensator (MTC) is 0.78 Mach (MD-88), 0.80 Mach (MD-90).

Flight Control Sensitivity at High Speed and High Altitude

An understanding of flight control sensitivity at high speed and high altitude is necessary for operators of modern day aircraft. There have been reports of passenger injuries due to over-controlling the aircraft during high altitude, high airspeed flight when overriding the control column with the autopilot engaged or after disengaging the autopilot with the disconnect switch.

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Pilots should understand that, in general, the aircraft is significantly more sensitive in pitch response (load factor) to column movement at cruise than it is at lower speeds associated with takeoff and landing. Similarly, for a given attitude change, the change in rate of climb is proportional to the true airspeed. For example, an attitude change at 290 knots KIAS at sea level that results in a 500 fpm rate of climb would result in approximately a 900 fpm rate if done at 290 knots KIAS at 35,000 feet. This is because 290 KIAS is equivalent to a TAS of approximately 290 knots at sea level and 490 knots at 35,000 feet. This characteristic is essentially true for small attitude changes, such as the kind used to hold altitude.

Other factors such as gross weight and CG also affect flight control sensitivity and stability, but as long as the CG is in the allowable range the handling qualities will be adequate. However, to avoid over-controlling the flight controls during high altitude high airspeed flight, smooth and small control inputs should be made after disengaging the autopilot.

Low Speed at Altitude

MD-88/90s have experienced events where speed falls below intended cruise mach. If aircraft speed gets slow enough it cannot be recovered without descending.

Onset scenarios are:

- Inappropriate use of VERT SPD in the climb or over aggressive “zoom” maneuver
- Lack of awareness of performance penalty associated with engine bleeds or failure to recognize PT2 probe icing. Engine anti-ice is required in accordance with Limitations in Vol. 1, including temperatures below -40°C SAT
- Lack of understanding of the limitations of holding in VNAV or selecting an inappropriately low holding speed.

Contributing factors include:

- Allowing the aircraft to approach the back side of the power curve
- Not crosschecking EPR with other engine instruments, especially N1
- Lack of vigilance in cruise, especially immediately after TOC.

Climb and cruise procedures include steps to bring focus to aircraft performance (determine maximum altitude and minimum speed).

- During climb:
  - APU fuel consumption (approximately 175 PPH) is not included in the fuel displayed.
  - The FMS will not calculate fuel consumption during single engine taxi (both fuel levers must be on).
  - Ensure FMS PERF data is accurate.

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- Use VNAV if available.
- Recall FMS OPT altitudes do not take into account the use of engine bleeds.
- Consider possibility for turbulence and in-flight maneuvering.

- During cruise:
  - Perform the Cruise procedure immediately after TOC.
  - Leave CL selected in the TRP.
  - Limit bank angle to 15°, if operationally feasible.
  - Fly the FMS-generated cruise speed.
  - Determine a minimum cruise airspeed by adding 10 knots to clean speed. Do not allow airspeed to fall below this speed in cruise, including holding.
  - Monitor engine performance, especially N1.

ETOPS

ETOPS is not approved for the aircraft.

Descent

Descent Planning

Determine the arrival and approach to be flown. If expecting an enroute descent, ensure there is a waypoint and altitude constraint on the LEGS page that provides a valid TOD point for a descent to the terminal area. If expecting a STAR or R/D (runway dependent) STAR, select the STAR, Approach and appropriate transitions. Verify the waypoints and any associated altitude and airspeed restrictions, including “Expect” constraints, match the ATC clearance and the charted Jeppesen procedure. Also reconcile all route discontinuities. If the STAR and/or runway is changed, complete the entire arrival and approach selection process again to prevent the possibility of incorrect routing or inadequate obstacle clearance. Two techniques for accomplishing a runway assignment change are RTAT-clean and Route 2.

RTAT - Clean

- Runway (Approach) - Select approach for new Runway assignment
- Transition (Approach Transition) - Select appropriate transition
- Arrival (re-select the current arrival with the new runway assignment)
- Transition (re-select the appropriate arrival transition, if needed)

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- "CLEAN" IS CRITICAL -- Close any discontinuities and ensure the proper sequence of waypoints. Bring the point just above the discontinuity into the boxes to preserve the constraints. Verify (and re-enter, if necessary) any and all airspeed/altitude constraints.

Note: Depending on the coding of the arrival, discontinuities may or may not be produced and depending on the order of selection, constraints may or may not be preserved. Because of these variables, it is imperative that both crewmembers verify all discontinuities are closed and waypoints and constraints are correct. Reference the ND to ensure the waypoint at the top of the LEGS page is still in front of the aircraft before pressing Execute.

Note: Runway changes greatly increase pilot workload. The captain should ensure one pilot is flying and managing the flight path while the other loads the FMS. Both pilots should not be "heads down" at the same time. Due to the high workload, if at any time the crew believes they are unable to comply with the arrival, immediately notify ATC and request vectors.

ROUTE 2

Using Route 2 for runway changes is highly recommended, because the steps are accomplished during preflight when the workload is low this technique greatly reduces errors. After the flight plan and anticipated landing runway are loaded in RTE 1, load the second most likely runway by selecting RTE 2 and enter the following:

- Origin - KXXX
- Destination - KXXX
- Runway (Second most likely Approach)
- Transition (Approach transition)
- Arrival (Flight plan STAR)
- Transition (Flight plan Arrival Transition, if needed)
- Clean - Remove discontinuities and verify (or enter) published or assigned airspeed/altitude constraints.

Note: Ensure an origin is loaded or there will be no vertical guidance when route 2 is activated. It is unnecessary to load the entire route, because the aircraft will already be on the arrival if RTE 2 is needed.

When issued a runway change:

- Select RTE 2 (RTE page 6R)
- Activate
- Direct To a point in front of the aircraft
- Verify waypoints and constraints
- Execute

Verify proper FMA annunciations

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When not required to fly the entire arrival (e.g., expect vectors to the approach at a waypoint), the subsequent waypoints may be deleted from the arrival for accurate destination ETAs and fuel estimates.

Flight deck workload typically increases as the aircraft descends into the terminal area. Distractions should be minimized and administrative and nonessential duties completed before descent or postponed until after landing. Perform essential duties early in the descent so more time is available during the critical approach and landing phases.

If expecting an enroute descent:

Operational factors and/or terminal area requirements may not allow following the optimum descent schedule. Terminal area requirements can be incorporated into basic flight planning, but ATC, weather, icing, and other traffic may require adjustments to the planned descent schedule.

Proper descent planning is necessary to arrive at the desired altitude at the proper speed and configuration. The distance required for the descent is approximately 3 NM/1,000 feet altitude loss for no wind conditions using ECON speed. Rate of descent is dependent upon thrust, drag, airspeed schedule, and gross weight.

Calculation of 3:1 Descent Ratio

As a backup to FMS generated TOD points, the 3:1 descent ratio can be used to plan and execute an idle descent. This descent ratio provides for a comfortable idle descent path by losing approximately 1,000 feet every 3 miles.

The basic equation is: (altitude to lose/1,000) x 3 = distance required

For example, if cruising at 35,000 feet and given a clearance to descend to 10,000 feet, the altitude lost equals 25,000 feet (35,000 - 10,000). In this example, the 3:1 calculation becomes 25,000 feet /1,000 times 3. Simply stated, 25 x 3 = 75. It will take approximately 75 miles to descend 25,000 feet using the 3:1 ratio. In order to arrive 30 miles from the field at 10,000 feet, add the 75 miles to the 30 miles resulting in a TOD point at 105 miles from the field. In order to properly use the 3:1 distance, a valid distance to the field or the crossing waypoint has to be available.

Continuously update the 3:1 calculation. For example, descending through 25,000 feet the aircraft is 60 miles from the field. 15,000 feet remains to be lost. 15 x 3 = 45 miles. Adding 45 miles to the end of descent at 30 miles from the field yields 75 miles needed if on the 3:1 descent. Since the aircraft is only 60 miles out, the aircraft is high and the descent rate needs to be increased.

Prior to descent, modify the calculated distance for expected conditions. Subtract mileage for strong headwinds or add mileage if a tailwind exists. Add mileage if planning to use air-foil anti-ice or if a speed reduction is expected.

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Use the Altitude Range Arc (green arc) to monitor the descent. The green arc displayed on the ND provides a visual indication of where the aircraft will intercept the altitude set in the MCP ALT window, based on the current rate of descent. If given a descent clearance to cross 30 miles from the field at 10,000 feet, create a corresponding fix on the LEGS page. Once the descent has started, monitor the green arc's position relative to the end of descent fix. The 3:1 descent ratio assumes a direct course to the field or waypoint. Any additional maneuvering adds distance to the descent allowing a shallower descent rate.

Descent Speed Determination

The default FMS descent speed schedule is an economy (ECON) descent from cruise altitude to the airport speed transition altitude. At the airport speed transition altitude, the airspeed is reduced to the airport speed restriction speed in the navigation database minus 10 knots. The speed schedule is adjusted to accommodate waypoint speed/altitude constraints displayed on the LEGS pages, and speed/altitude constraints displayed on the DES page. Speeds entered on the cruise page will be propagated to the DES page. If desired, the ECON speed schedule can be modified by alternate Mach, Mach/IAS, or IAS values on the DES page If the flight plan top of descent cost index is 55, select POLICY on the DES page which will provide a CRZ mach/300KIAS descent speed profile. POLICY can be selected during preflight and is the preferred method. An alternate method is to change the cost index to 55 at top of descent.

Descent Path

An FMS idle path descent is the most economical descent method. At least one waypoint-related altitude constraint below cruise altitude on a LEGS page is required to generate a descent path. An idle path will be created from the next lower altitude constraint below cruise back to cruise altitude and displays a TOD. A vertical descent path (V-Path) will be created between all subsequent altitude constraints.

The path is based on the descent speed schedule, any entered speed/altitude constraints or forecast use of anti-ice. The path reflects descent wind values entered on the DESCENT FORECAST page.

If using FMS OVRD to control speed while in the approach mode the aircraft will maintain the path and not descend below, prior to the next altitude constraint. The autothrottles will add thrust to maintain desired speed.

Descent Constraints

Descent constraints may be automatically entered in the route when selecting an arrival procedure, or manually entered through the MCDU.

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For descents in pitch modes other than VNAV, the MCP altitude must be set at the next altitude constraint, or as published in the Vol. 1 for an instrument approach.

Shallow vertical path segments may result in the autothrottle supplying partial thrust to maintain the target speed. Vertical path segments steeper than an idle descent may require the use of speedbrakes for speed control. Deceleration requirements below cruise altitude (such as at 10,000 MSL) are accomplished based on a rate of descent of approximately 500 fpm. When a deceleration is required at top of descent, it is performed in level flight.

FMS Override

VNAV speed intervention (FMS override) can be used to respond to ATC speed change requirements. Select FMS OVRD and set the new speed to comply with ATC speed requirements. Then program the new speed in the FMS. If the assigned speed is considered temporary, remaining in FMS override is preferred until the speed requirement is no longer needed and then deselecting FMS OVRD. If on a descent path while using FMS override, speed will be primary and vertical deviations from the path may occur This may cause the aircraft to not make an altitude constraint. The aircraft, however, will not descend below the MCP altitude or large font altitudes in the MCDU. If below the path using FMS override, the FMA speed window will change to (CLMP XXX) and the pilot adjusts the throttles to vary the rate of descent. All mandatory speed constraints must be manually set by the crew. FMS override is the recommended mode while operating in VNAV in the terminal area.

Note: The default airport transition speed 240/10,000 feet will not be honored while in FMS OVRD.

With VNAV engaged using FMS OVRD on an RNAV Visual Approach or after passing the fix prior to the final approach fix, the FMS automatically switches to the Approach Mode. In the approach mode the FMS once again considers the descent path primary and may capture the descent path. Upon capturing the descent path the throttles will come out of the CLMP mode and attempt to maintain the speed set in the autothrottle SPD/MACH window, while also maintaining the descent path. Because this happens automatically the crew may not be aware the change has occurred. In this mode the aircraft may not maintain the selected speed without pilot action.

Early Descent from Cruise

When descending before the aircraft reaches the TOD, consideration should be given to choosing the best VNAV descent mode, either a Cruise Descent or a descent using DES NOW. The key factors to consider are distance from TOD, speed, and altitude to lose.

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When changing altitude during the flight (ride or traffic) and the TOD is approximately 100 nm or greater ahead, perform a Cruise Descent. Set the lower cruise altitude in the MCP and CRZ page. Select VNAV and the aircraft will descend to the lower altitude at the speed that is active in the CRZ page. The autothrottles will retard the throttles and CLMP. The aircraft will begin a descent at approximately 1,500 fpm. The throttle may then be manually adjusted for the desired rate of descent. When ECON is the active mode, changing the cruise altitude will also cause the cruise speed to change; the lower the new altitude, the lower the new cruise speed.

Within approximately 100 nm of TOD the use of DES NOW is recommended. Set the lower cruise altitude in the MCP and select the DES NOW prompt on the Descent page. The autothrottles will retard the throttles and CLMP. The aircraft will begin a descent at approximately 1,500 fpm. Once the throttles are in CLMP increase power to maintain a shallow rate of descent of between 500 and 1,000 fpm. This increases fuel efficiency by allowing the aircraft to intercept the idle path at a higher altitude. It will maintain this descent until intercepting the idle descent path, at which time the throttles will retard to idle and the aircraft will fly the calculated descent path. If descending on the path the FMS will increase or decrease airspeed as necessary to stay on the vertical path. Path is primary, speed is secondary. ATC-assigned speeds may not be maintained. The FMS will correct any deviations from below the VNAV path through throttle position. For deviations above the path, an airspeed increase above the target of 15 knots when above 10,000 feet or 10 knots when below 10,000 feet will cause DRAG REQUIRED message to be annunciated on the MCDU scratchpad. If the deviation above the path is not corrected the aircraft will depart the path and may not make the target altitude constraint.

Ensure all variables involved such as wind, use of anti-icing, etc., are programmed so the VNAV function of the FMS can make its crossing restriction. Monitor PATH ERROR on the DES page.

Variables while on the idle descent path (ATC, traffic, winds) may cause the aircraft to deviate from assigned airspeeds or miss altitude constraints. The recommended technique for descending from cruise is to parallel or shadow the idle descent path.

- Reset MCP altitude window to a lower altitude.
- Select and execute the DES NOW prompt on the DES page at a point 5 to 7 miles prior to the top of descent point or 3 to 5 miles prior to the path if already in a shallow descent.
- When the throttles CLMP retard them to Idle.

The aircraft is now just short of the idle path and will maintain the speed displayed on the DES page. The 3 to 5 mile buffer/pad will help ensure the aircraft can make assigned altitude constraints.

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Approaching Top-of-Descent (TOD)

If a lower altitude has not been selected in the MCP when within 2 minutes of the TOD point, a “RESET FGCP ALTITUDE” message appears on the FMS scratchpad. If the TOD point is reached without a lower altitude set in the MCP, the DES mode will become active and the aircraft will remain in VNAV at current altitude. If a lower altitude is set in the MCP the aircraft will begin to descend.

VNAV Descent From Above Path

When a lower altitude is selected in the MCP and the aircraft is “above path”, e.g. when ATC has held the aircraft at cruise altitude beyond the planned TOD point, selecting VNAV causes the throttles to retard to idle and FMS IDLE to be displayed in the FMA speed window. The active DES mode command speed will be flown, but not exceeded, to regain the path. The pilot must use drag devices (and/or increase speed) to return to the path. Once within 150 feet, the path is regained and, if needed, airspeed will then be sacrificed in order to stay on the path. If the pilot chooses to accept an increase in airspeed to recapture the path by using FMS override, the pilot will not regain the path in the descent.

Other Modes of Descent

CAUTION: Do not actuate the pitch wheel when nearing altitude capture. This will disable the ALT CAP mode and result in an altitude deviation. Confirm all MCP changes are annunciated on the FMA.

CAUTION: Changing the barometric altimeter setting while in the ALT CAP mode causes the autopilot to level the airplane above or below the selected altitude. However, resetting the barometric altimeter while in VNAV CAP will not interfere with level off at selected altitude.

IAS/MACH

When VNAV use is not desired, IAS/MACH mode is normally used for large changes in altitude (more than 2,000 feet). It will provide a rate of descent based upon thrust setting and will command a pitch attitude to acquire and maintain the selected IAS/MACH.

- Select a lower altitude in the MCP altitude window.
- Start the aircraft tracking down by actuating the pitch wheel. This will place the autopilot in the vertical speed mode.
- Select IAS/MACH on the MCP.
- Rotate the pitch wheel to the desired airspeed or mach.
- Retard the throttles manually to achieve the desired rate of descent.

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Vertical Speed

When VNAV use is not desired, vertical speed (V/S) mode is normally used for small changes in altitude (approximately 2,000 feet or less) and for non-precision approaches. It will provide a constant rate of descent.

- Select a lower altitude in the MCP altitude window.
- Push the vertical speed button (this is only necessary if operating in the IAS/Mach mode).
- Rotate the pitch control wheel to the desired rate of descent.
- The autothrottles will retard only to the ATS low limit. Further throttle reduction must be accomplished manually.

Descent Rates

The following Descent Rate table provides typical rates of descent below 20,000 feet with idle thrust and speedbrakes extended or retracted.

Target Speed	Rate of Descent (Typical)	
	Clean	With Speedbrake
0.78M / 280 knots	2,000 fpm	3,500 fpm
250 knots	1,700 fpm	2,800 fpm
210 knots slats extended	1,600 fpm	2,200 fpm

Normally, descend with idle thrust and in clean configuration (no speedbrakes). Maintain cruise altitude until 5 to 7 nm prior to the TOD and then descend 3 to 5 nm short of the descent path. Deviations from this schedule may result in arriving too high at destination and require circling to descend, or arriving too low and far out requiring extra time and fuel to reach destination.

The speedbrake may be used to correct the descent profile if arriving too high or too fast.

A good crosscheck is to be at 10,000 feet AFE, 30 miles from the airport, at 250 knots. Then use the 3:1 descent path based on flying distance to the runway to establish the descent for the approach.

Losing airspeed can be difficult and may require a level flight segment. For planning purposes, it requires approximately 60 seconds and 7 nm to decelerate from 320 to 250 knots in level flight without speedbrakes. It requires an additional 25 seconds and 2 nm to decelerate to flaps up maneuver speed at average gross weights. This equates to approximately 10 knots/nm at level flight. Using speedbrakes to aid in deceleration reduces these times and distances by approximately 50%.

Maintaining the desired descent profile and using the map mode to maintain awareness of position ensures a more efficient operation.

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Speedbrakes

The PF should keep a hand on the speedbrake lever when the speedbrakes are used in flight. This helps prevent leaving the speedbrake extended when no longer required.

Use of speedbrakes does not appreciably affect aircraft roll response. While using the speedbrakes in descent, allow sufficient altitude and airspeed margin to level off smoothly. Retract the speedbrakes before adding thrust.

There is no maximum airspeed restriction for extension. Deployment of the speedbrakes will produce some buffeting and a pitch down tendency. Retracting the speedbrakes will result in pitch up. In either case, anticipation of the effect and proper use of the spoiler/speedbrake lever will result in a smooth transition between configurations.

Note: Speedbrakes must not be used with flaps extended in flight. Do not extend landing gear with speedbrakes deployed. Speedbrakes may be used with or without slats extended. Do not move spoiler/speedbrake lever to ground spoiler position in flight.

When descending with the autopilot engaged and the speedbrakes extended at speeds near VMO/MMO, the airspeed may momentarily increase to above VMO/MMO if the speedbrakes are retracted quickly. To avoid this condition, smoothly and slowly retract the speedbrakes to allow the autopilot sufficient time to adjust the pitch attitude to maintain the airspeed within limits.

When the speedbrakes are retracted during altitude capture near VMO/MMO, a momentary overspeed condition may occur. This is because the autopilot captures the selected altitude smoothly by maintaining a fixed path while the thrust is at or near idle. To avoid this condition, it may be necessary to reduce the selected speed and/or descent rate prior to altitude capture or reduce the selected speed and delay speedbrake retraction until thrust is increased to maintain level-off airspeed.

Flaps and Landing Gear

Normal descents are made in the clean configuration to pattern or instrument approach altitude. If greater descent rates are desired, extend the speedbrakes. When thrust requirements for anti-icing result in less than normal descent rates with speedbrakes extended, or if higher than normal descent rates are required by ATC clearance, additional drag may be used in accordance with aircraft limitations (e.g., gear, speedbrakes, flaps).

Note: Using the landing gear for increased drag potentially increases passenger discomfort and decreases gear door life.

When slowing to the desired speed, select the next slat/flap setting prior to decelerating below the maneuvering speed for that slat/flap setting.

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Air Foil Icing During Descent

CAUTION: Failure to follow the recommended anti-ice procedures can result in decaying airspeed, engine stall, overtemperature, engine damage, or engine failure.

The use of AIR FOIL anti-ice and the increased thrust required increases the descent distance. Therefore, proper descent planning is necessary to arrive at the initial approach fix at the correct altitude, speed, and configuration. The anticipated AIR FOIL anti-ice use altitude should be entered on the DESCENT FORECAST page to assist the FMS in computing a more accurate descent profile.

Throttle Technique

The LOW LIMIT setting on the autothrottles may not allow the aircraft to decelerate at adequate rates or maintain selected airspeed when at low altitudes and slow airspeeds. This occurs when a deceleration or descent is initiated with the speed select knob, VERT SPD, or while tracking the glideslope. In this instance, the throttles only retard to the LOW LIM, a higher power setting than idle, and the aircraft does not decelerate or the airspeed may increase during descent. Since the MD-88/90 engines exhibit a relatively high residual thrust while at LOW LIM, initiate terminal area descents with the pitch control wheel (vertical speed) for a smooth entry, then select IAS mode and retard the throttles to idle. Rate of descent can be adjusted with power and desired airspeed will be maintained. Approximately 500 feet before level off, increase the power setting to shallow out the descent (move the throttles forward until the red gear warning lights extinguish). This will provide for a smooth application of power by the autothrottles during level off and prevent a throttle burst. The use of VNAV precludes this issue.

When using manual throttles, the following target EPR settings work for most approach and terminal area weights:

Speed	Configuration	Power (MD-88)	Power (MD-90)
250	CLEAN	1.25	1.07
210	SLATS	1.25	1.07
180	FLAPS 11	1.25	1.07
160	FLAPS 15	1.30	1.10
FINAL	FLAPS 28	1.20	1.05
FINAL	FLAPS 40	1.25	1.10

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Holding

When informed of an in-flight delay, to save fuel:

- Slowing down is a more desirable alternative than extended off course vectors. Coordinate the speed reduction with ATC.
- Stay high as long as possible to minimize fuel flow.
- Request extended legs in the holding pattern since fuel flow increases in turns.

Protected holding airspace is based on using specified maximum speeds and entry procedures. These procedures must be followed closely unless a specific clearance to deviate is obtained.

Maintain clean configuration if holding in icing conditions or in turbulence.

In extreme wind conditions or at high holding speeds, the defined holding pattern protected airspace may be exceeded. However, the holding pattern depicted on the map display will not exceed the limits.

Holding Airspeeds

For maximum holding airspeeds, refer to the Airway Manual, Ops Specs, Maximum Holding Airspeeds.

CAUTION: Holding at altitudes above FL250 may be Buffet Limited. If the aircraft configuration falls with in the Buffet Limited (grey shaded) area, holding is not authorized.

Start reducing to holding airspeed three minutes before arrival time at the holding fix so that the airplane crosses the fix, initially, at or below the maximum holding airspeed. Establish holding airspeed based on altitude and aircraft configuration. Normally, hold in a clean configuration. Obtain holding speed from the MCDU hold page, the Takeoff and Landing Data Speed Booklet or the Holding/Descent section of the ODM.

Note: The holding speed displayed on the MCDU HOLD page is a minimum speed for straight-and-level flight and normally increases when starting a turn. However, it is recommended that crews hold at a minimum of clean speed plus 10 knots to reduce the chance of experiencing buffet in a turn.

Note: Delta Air Lines recommends not using the FMS generated speed while holding. If holding in VNAV, use FMS override and add 10 knots to the FMS generated speed.

Note: These speeds do not take into account the ICAO or FAA maximum holding speeds.

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If the recommended holding speed exceeds the ICAO or FAA maximum holding speed for a given altitude, request clearance to hold at the higher speed. Holding speeds in the FMS provide an optimum holding speed based upon fuel burn and speed capability. The holding speed target is the IAS value that corresponds to 1.3g buffet minimum speed or the 1.5 Vstall speed (whichever is higher) for clean configuration. Holding speeds are also defined for flaps-up/slats extend, and the target speed is 1.5 Vstall for this configuration.

Holding Airspeeds Not Available from the FMS

If holding speed is not available from the FMS, refer to the Holding Speeds in the Landing Data Speed Book, or ODM. Hold a minimum of 10 knots above the published holding speed.

Holding Pattern Exit

When exiting the holding pattern, the FMS LEGS page must be updated to enable proper waypoint sequencing. This can be done by:

- Selecting the EXIT HOLD prompt (6R) on the FMS HOLD page. When EXIT ARMED is executed, the aircraft will cross the holding fix and exit holding. If executed when outbound in the holding pattern the airplane will immediately turn inbound and exit holding when the fix is crossed.
- Proceeding direct to a waypoint on the LEGS page by making it the active waypoint (1L).
- Selecting a heading and then deleting the holding pattern from the LEGS page. Ensure the next downstream waypoint is active to ensure proper waypoint sequencing.

Note: Intercepting a localizer course while in an active holding pattern will exit the holding pattern but proper waypoint sequencing will not take place if EXIT HOLD is not ARMED and executed or if the next downstream waypoint is not made active.

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Approach and Missed Approach — Chapter 5
Table of Contents — Section TOC

Approach 5.1
Instrument Approaches 5.1
Approach Category 5.1
Approach Clearance 5.2
Procedure Turn 5.2
Radio Altimeter 5.2
Sidestep 5.2
Maneuver Margin 5.3
Quick Reference Landing Length 5.3
Flap Configurations for Approach and Landing 5.4
Flap Setting for Landing 5.4
Flap Extension 5.4

ILS Approach 5.5
ILS Approach Profile 5.5
ILS Approach Profile 5.7
ILS CAT I or LDA with GS Approaches 5.7
Approach 5.8
ILS Autoland Approach Profile 5.12
ILS CAT II or SA CAT II Approaches 5.14
ILS CAT III Approaches 5.17
ILS PRM Approach 5.25
ILS Approach - Landing Geometry 5.27

Non - ILS Instrument Approaches 5.31
Instrument Approach Using V/S Profile 5.31
Non-ILS Approach Considerations 5.33
ILS (GS Out) or LDA (without GS) or LOC or VOR Approaches 5.34
LOC (BACK CRS) or NDB Approach Guide 5.36

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HDG SEL & VERT SPD 5.36
General 5.38
Non - ILS Instrument Approaches - General 5.38
Non-ILS Instrument Approach Using V/S 5.41

Circling Maneuver 5.43
Circling Approach Profile 5.44
Circling Maneuver - General 5.46
Obstruction Clearance 5.46
Missed Approach - Circling 5.48

Visual Approach 5.49
Visual Approach - General 5.49
Downwind and Base Leg 5.49
Internal Visual Cues 5.49
Vertical Guidance On a Visual Approach 5.50
Final Approach 5.50
Visual Traffic Pattern Profile 5.51

Engine Inoperative Approach Operations 5.52
ILS Approach Profile - One Engine Inoperative 5.53
ILS Approach 1 ENG INOP FMA Progression 5.54
ILS Approach - Engine Inoperative 5.55
Engine Inoperative, Rudder Trim - All Instrument Approaches . . 5.55
Non-ILS Instrument Approach Profile - One Engine Inoperative . 5.56
Circling Maneuver Profile - One Engine Inoperative 5.59
Engine Failure On Final Approach 5.61
Go-Around and Missed Approach Profile - One Engine Inoperative 5.62
Engine Failure During Go-Around and Missed Approach 5.66

Go-Around and Missed Approach - All Approaches 5.67
Go-Around and Missed Approach Profile - All Approaches 5.67

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Go-Around and Missed Approach - All Engines Operating 5.69
Go-Around after Touchdown 5.73

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Approach and Missed Approach Chapter 5

Approach
Instrument Approaches

CAUTION: Building approaches not in the FMS data base is discouraged when operating below 10,000 feet.

WARNING: Do not attempt to land from an unstable approach.

All safe instrument approaches have certain basic factors in common. These include good descent planning, careful review of the approach procedure, accurate flying, and good crew coordination. Thorough planning is the key to a safe, unhurried, professional approach.

Ensure the waypoint sequence on the LEGS page, altitude and speed restrictions, and the map display reflect the ATC clearance. Last minute ATC changes or constraints may be managed by appropriate use of the MCP heading, altitude, and airspeed selectors. Updating the waypoint sequence on the LEGS page should be accomplished only as time permits.

During high workloads, it is a good technique to have the PM set up the approach prior to the briefing.

Complete the approach preparations before arrival in the terminal area. Set decision altitude or height DA(H), derived decision altitude (DDA), or minimum descent altitude or height MDA(H). Do not completely abandon enroute navigation procedures even though ATC is providing radar vectors to the initial or final approach fix. Check ADF/VOR selector set to the proper position. Verify ILS, ADF, or VOR are tuned and identified if required for the approach.

Note: The requirement to tune and identify navaids can be satisfied by aurally identifying the navaid.

Check that the marker beacon is selected on the audio panel, if needed. The course and glideslope signals are reliable only when their warning flags are not displayed, localizer and glideslope pointers are in view, and the ILS identifier is received. Confirm the published approach inbound course is set or displayed.

Do not use radio navigation aid facilities that are out of service even though flight deck indications appear normal. Radio navigation aids that are out of service may have erroneous transmissions that are not detected by aircraft receivers and no flight deck warning is provided to the crew.

Approach Category

Refer to the Airway Manual, Ops Specs, IAP.

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Approach Clearance

When cleared for an approach and on a published segment of that approach, the pilot is authorized to descend to the minimum altitude for that segment. When cleared for an approach and not on a published segment of the approach, maintain assigned altitude until crossing the initial approach fix or established on a published segment of that approach. If established in a holding pattern at the final approach fix, the pilot is authorized to descend to the procedure turn altitude when cleared for the approach.

If using a VNAV path prior to final approach fix, all altitude and speed constraints must be entered either manually, by selecting a published approach, or by a combination of both. When properly entered, the VNAV path profile complies with all altitude and airspeed constraints. Crossing altitudes may be higher than the minimum altitudes for that segment because the VNAV path is designed to optimize descent profiles.

When conducting an instrument approach from a holding pattern, continue on the same pattern as holding. Turn inbound on the procedure turn heading.

Procedure Turn

On most approaches the procedure turn must be completed within specified limits, such as within 10 nm of the procedure turn fix or beacon. The FMS-depicted procedure turn, or holding pattern in lieu of procedure turn, complies with airspace limits. The published procedure turn altitudes are normally minimum altitudes.

The procedure turn size is determined by the ground speed at the IAF.

Adjust time outbound for airspeed, wind effects, and location of the procedure turn fix. If the procedure turn fix is crossed at an excessively high ground speed, the procedure turn protected airspace may be exceeded. The procedure turn should be monitored using the map to ensure the aircraft remains within protected airspace.

Refer to the Airway Manual, Ops Specs, IAP.

Radio Altimeter

A Radio Altimeter (RA) is normally used to determine DH when a DA(H) is specified for Category II, or Category III approaches. Procedures at airports with irregular terrain may use a marker beacon instead of a DH to determine the missed approach point. The radio altimeter may also be used to crosscheck the primary altimeter over known terrain in the terminal area. The radio altimeter is not used for determining CAT I DA/ MDA(H) on instrument approaches. Also, it should not be used for approaches where use of the radio altimeter is not authorized (RA NOT AUTHORIZED).

Sidestep

Refer to the Airway Manual, Ops Specs, IAP.

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Maneuver Margin

When slowing in the terminal area, extend slats or slats and flaps prior to decelerating below maneuver speed for the current configuration. This will allow for full maneuvering capability.

Full maneuver margin exists for all normal landing procedures whenever speed is at or above the maneuver speed for the current flap setting. During a go-around at flaps 15, go-around speed is not a maneuvering speed. Limit bank angle to 15°.

Airspeeds recommended for non-normal flight profiles are intended to restore near normal maneuvering margins and/or aerodynamic control response.

The configuration changes are based on maintaining full maneuvering capabilities unless specified differently in individual non-normal procedures. It is necessary to apply wind additives to the VREF speeds. Refer to chapter 1, Command Speeds, Landing, for an explanation of wind additives.

Quick Reference Landing Length

Flap 28 or 40 approaches and landings may be conducted normally without reference to the ODM landing distance tables according to the following guidance.

Quick Reference Landing Length		
Includes a 15% Safety Margin Refer to the ODM for landings with abnormal configurations, MCOs affecting landing distance, or if above the maximum landing weight (MLW).		
Quick Reference Minimum Runway Length	88	90
	7,000 feet	

Assumptions:

- Airport elevation 4,000 ft or lower (including KSLC and KDEN)
- Touchdown no later than 1,500 ft. from threshold
- Up to Max Landing Weight
- Autobrakes Max
- Dry runway
- Zero wind and runway slope
- Two engines at target reverse thrust

Additional stopping performance is available by:

- Increased manual braking
- Landing at a lower altitude
- Landing at a lower weight

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Flap Configurations for Approach and Landing

During maneuvering for an approach, when the situation dictates an earlier than normal speed reduction, the use of flaps 11, 15, or 23 with the gear up is acceptable.

Flap Setting for Landing

Flaps 28 Landing

When operational considerations allow, crews are encouraged to use flaps 28 for final approach and landing. Landing with flaps 28 has a minimal effect on final approach speed (approximately 5 knots higher than flaps 40 landing speed), landing distance, and body attitude at touchdown. Using flaps 28 for final approach and landing reduces fuel burn when compared to flaps 40. Flaps 28 will also provide better control response in gusty wind conditions.

Flaps 40 should be used when landing on contaminated or short runways.

A flaps 40 landing may be appropriate when:

- Available landing distance is a factor
- The runway is contaminated
- The approach is steeper than normal due to ATC requirements
- Using engine and airfoil anti-ice, which require higher than normal engine power
- High outside air temperature or high density altitude airport where brake temperature is a factor
- Overweight landing
- Low visibility CAT II/III approaches (reduced deck angle by 1° for better visibility).

Flaps 28 will increase landing distance approximately 300 feet.

Refer to ODM, section 6, for specific charts.

Flap Extension

During flap extension, selection of the flaps to the next flap position should be made when approaching, and before decelerating below, the maneuver speed for the existing flap position.

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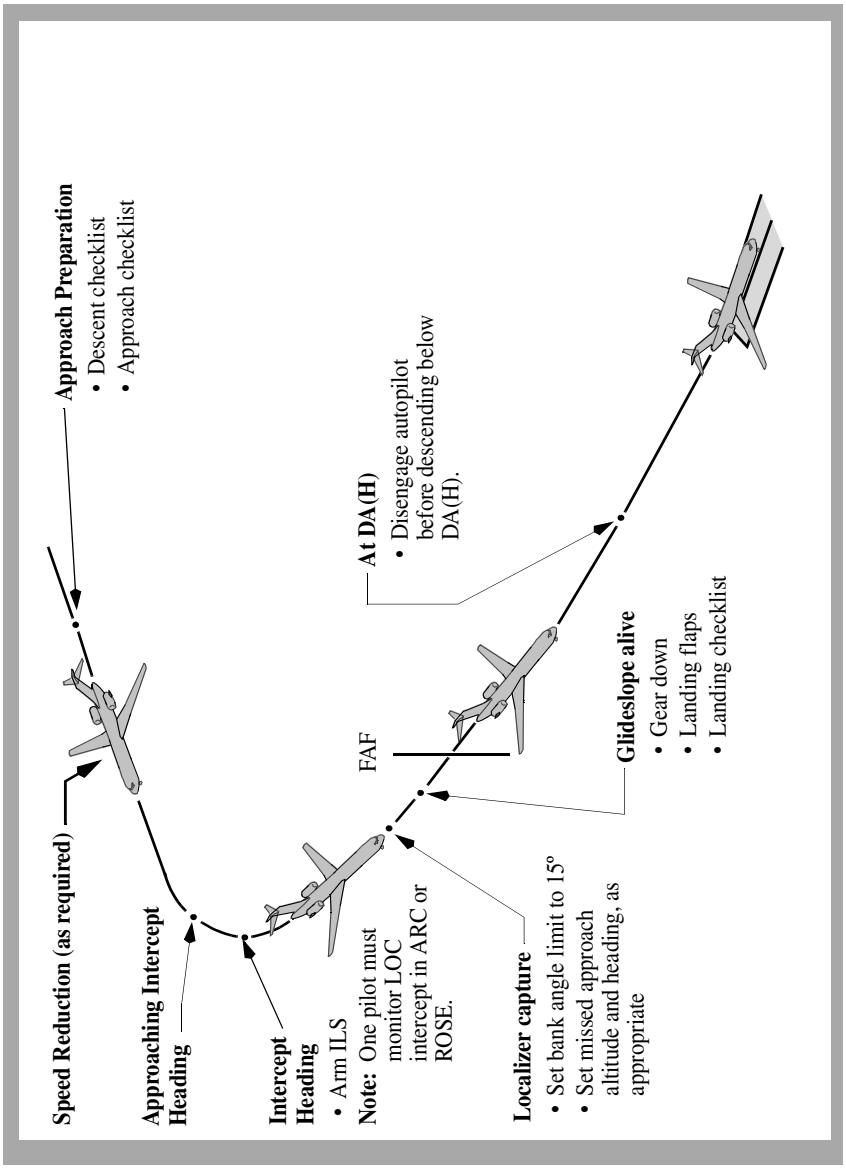
ILS Approach

ILS Approach Profile



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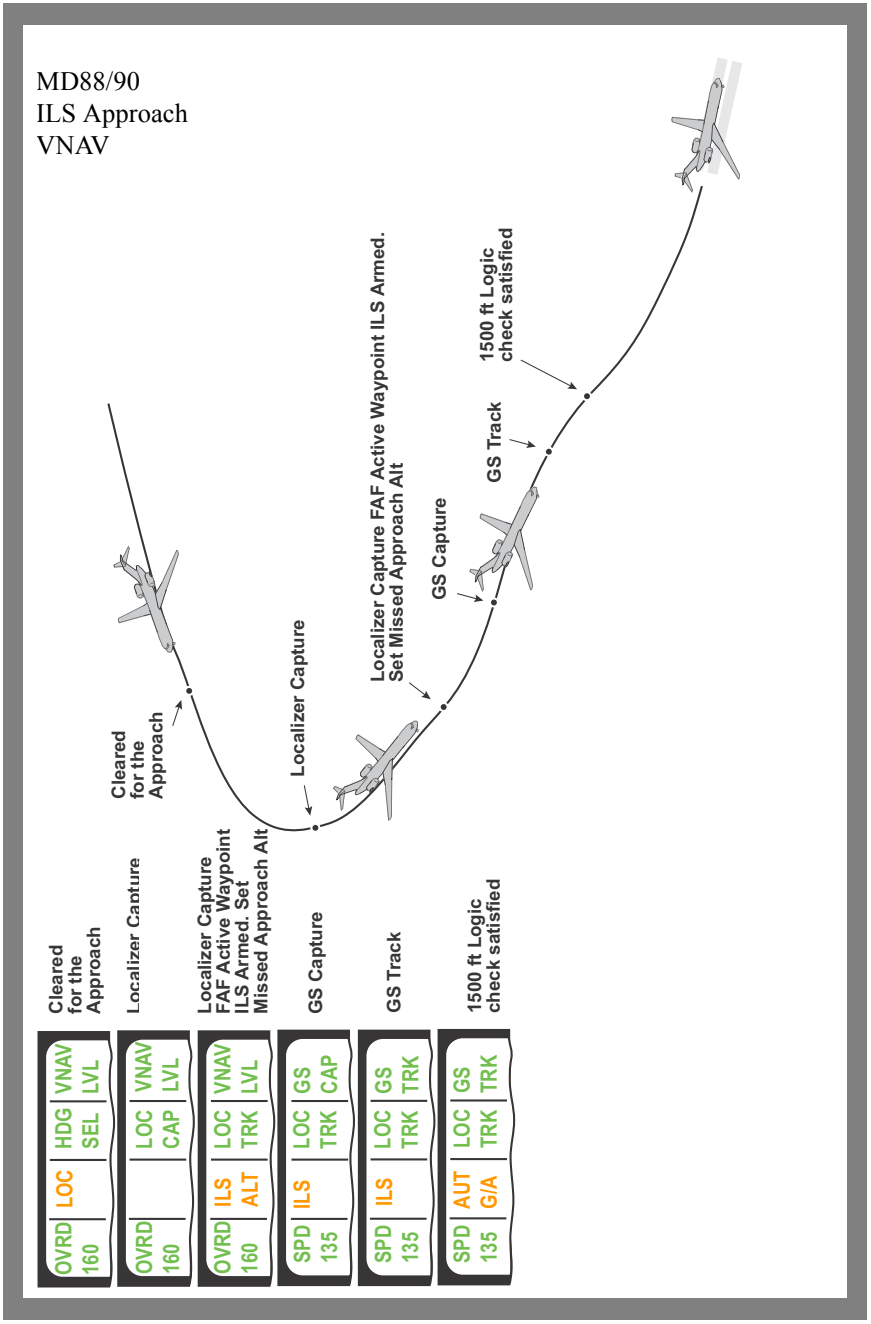
ILS Approach VNAV FMA Progression



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ILS Approach Profile

ILS CAT I or LDA with GS Approaches

For inoperative equipment, refer to the QRH, Non-Normal Ops Info tab, ILS Approach Equipment Requirements.

For any inoperative ground based equipment, refer to the Airway Manual, Ops Specs, IAP.

For ILS Precision Runway Monitor (PRM) Approach, refer to the ILS Precision Runway Monitor (PRM) Approach Breakout Procedures Approach Guide in Vol 1.

Note: Approach may continue to DA(H) if established on the final segment and the controlling RVR goes below minimums. Specific foreign country exceptions may apply. For further information, refer to the Airway Manual, Ops Specs, IAP.

Airport diagram/SMGCS..... Review

The First Officer should have the applicable chart out and available for taxi assistance.

Autopilot..... As required

If operable, both the Autopilot and Flight Director will be utilized for all ILS approaches when the reported weather is below 4,000 feet RVR or 3/4 mile.

The autopilot must be disconnected no later than DA(H) unless conducting an approach using the autoland system.

FMS approach procedure..... Select and verify

Select the approach procedure on the ARRIVALS page. Verify FMS LEGS page waypoints and altitude constraints match the charted approach.

Flight and nav instruments..... Set

Tune and identify the frequency for the selected approach.

Set the ILS frequency and front course.

Minimums..... Set DA

Set radio altimeter to OFF.

Set baro altimeter to DA(H)

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When cleared for the approach:

ILS..... Select

AUTO LAND may be used. Refer to CAT II or III Approaches for more information.

One pilot must be in ARC or ROSE mode to verify capture of the correct localizer course than may return to the ND MAP display. After localizer capture, the expanded localizer on the PFD may be used.

Select when established on a published inbound segment of the approach or when on a final approach course intercept heading. Adhere to all published step down fix altitudes located outside the final approach segment.

No later than 1,000 feet AGL:

Missed approach altitude.....Set

Set lowest initial level off altitude on missed approach procedure. Confirm bank angle and heading on the MCP.

Execute a Missed Approach for any of the following:

- Criteria listed in Airway Manual, Ops Specs, IAP, or
- In IMC, a navigation radio or flight instrument failure occurs which affects the ability to safely complete the approach, or
- In IMC, full scale deflection of the localizer or glide slope, or
- In IMC, when the navigation instruments show significant disagreement.

Approach

ILS Approach - General

The ILS approach flight pattern assumes all preparations for the approach, such as review of approach procedure and setting of minima and radios, are complete. It focuses on crew actions and avionic systems information. It also includes unique considerations during low weather minima operations. The flight pattern may be modified to suit local traffic and ATC requirements.

Transitioning to Final Approach

Both pilots should not be “heads-down” during the approach. In some cases, such as high density traffic, or when an arrival procedure is used only for reference, revising the FMS may not be appropriate.

Throughout the approach transition and approach, adjust the map display and range to provide a scaled plan view of the area.

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The arrival and approach transition may be flown using HDG SEL, VOR/LOC or NAV for lateral tracking and VNAV, IAS, or V/S for altitude changes. When not using VNAV to descend, use VERT SPD for small altitude changes. this permits a more appropriate descent rate. NAV and VNAV may not be used from the final approach fix inbound.

If being radar vectored to the final approach and displaying the arrival procedure or approach transition is not desired, perform a DIRECT TO or INTC LEG TO the FAF, OM, or appropriate fix, to simplify the navigation display. This provides:

- A display of distance remaining to the FAF, OM, or appropriate fix
- A depiction of cross track error from the final approach course
- NAV capability during the missed approach procedure
- If direct to the fix, VNAV capability during the initial part of the approach procedure.

When using VNAV and on vector for the approach a DESCENT PATH INHIBITED message may appear in the scratchpad. The FMS will display this message if the following path parameters are exceeded:

- Track angle error greater than 90°
- Cross track error greater than 21 miles
- A command roll error greater than 20° (i.e., more than 20° angle of bank required to turn to the active waypoint).

The aircraft may continue a descent while in VNAV, but there will be no PATH ERROR reference on the DES page. If the aircraft returns to a position satisfying the parameters listed above, the message will disappear and accurate PATH ERROR will be displayed on the DES page. Selecting DIRECT TO a point on the approach in front of the aircraft will keep these parameters from being exceeded an accurate PATH ERROR to be displayed. It may be necessary to update NAV by occasionally reselecting DIRECT TO the appropriate fix as the aircraft flies away from the path while being vectored.

When operating in speed intervention (FMS OVRD) or an autothrottle SPD mode, timely speed selections minimize throttle movement during the approach. This reduces cabin noise levels and increases fuel efficiency. When flaps are extended, select the next lower speed just before additional configuration drag takes effect.

When maneuvering to intercept the localizer, decelerate and extend flaps to 11 or 15.

Select ILS or LND mode when:

- The ILS is tuned and identified
- The aircraft is on an inbound intercept heading
- Both localizer and glideslope pointers appear on the attitude display in the proper position
- Clearance for the approach has been received.

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After selecting, observe the ILS or LND flight mode annunciations are armed.

One pilot will display raw data on the ND to monitor LOC capture. If needed, use HDG SEL to establish an intercept heading to the final approach course.

Altitude Constraints on Published Instrument Approaches

The ILS glideslope is a fixed angle from the runway regardless of temperature. On warmer than standard days, true altitude is higher than aircraft indicated altitude. Conversely, when colder than standard temperatures exist, true altitude is below aircraft indicated altitude. Using the ILS glideslope prior to the published Precision Final Approach Fix (PFAF), Glideslope Intercept Point or "Feather" when temperatures are higher than standard can place the aircraft below minimum crossing altitudes for fixes prior to the PFAF.

The use of VNAV prior to the PFAF when cleared for the approach protects against violating an altitude constraint. Once all altitude constraints prior to the PFAF have been met, intercept the ILS glideslope for the remainder of the approach. For significant hot or cold temperature deviations, selecting V/S and adjusting the descent rate may be needed to assist with glideslope capture prior to the PFAF, depending on the amount of deviation.

Note: Making the altitude prior to the FAF a hard altitude will aid in G/S capture.

Final Approach

At localizer capture, select the heading to match the inbound course or missed approach heading and set the bank angle limiter to 15°. For normal localizer intercept angles, very little overshoot occurs. Bank angles up to 30° may be commanded during the capture maneuver and is not limited by the position of the bank angle selector or intercept speeds below maneuvering speed. For large intercept angles or intercept speeds greater than 180 KIAS, some overshoot can be expected.

Use the map display to maintain awareness of distance to go to the final approach fix. When the glideslope pointer is at one dot, or at approximately 1800-2000 AFE if already tracking the glide slope, extend the landing gear, set VREF + 5 knots or VREF + wind additive if landing manually, select landing flaps and do the landing checklist. The pilot monitoring should continue standard call outs during final approach and the pilot flying should acknowledge call outs.

Check for correct crossing altitude when crossing the final approach fix (FAF or OM).

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There have been incidents where airplanes have captured false glideslope signals and maintained continuous on glideslope indications as a result of an ILS ground transmitter erroneously left in the test mode. False glideslope signals can be detected by crosschecking the final approach fix crossing altitude and VNAV path information before glideslope capture. A normal pitch attitude and descent rate should also be indicated on final approach after glideslope capture. Further, if a glideslope anomaly is suspected, an abnormal altitude range-distance relationship may exist.

This can be identified by crosschecking distance to the runway with altitude or crosschecking the airplane position with waypoints indicated on the navigation display. The altitude should be approximately 300 feet HAT per nm of distance to the runway for a 3° glideslope.

If a false glideslope capture is suspected, perform a missed approach if visual conditions cannot be maintained.

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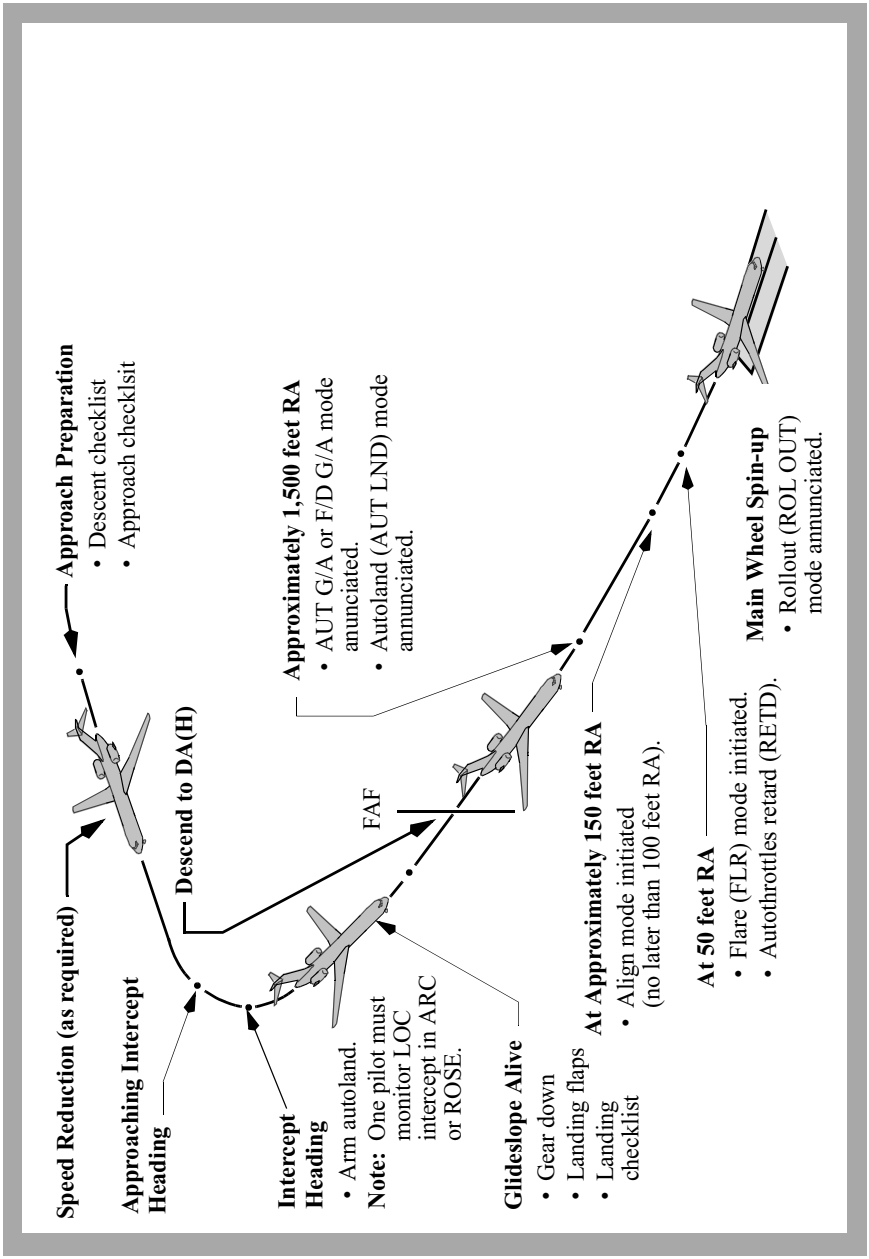
ILS Autoland Approach Profile



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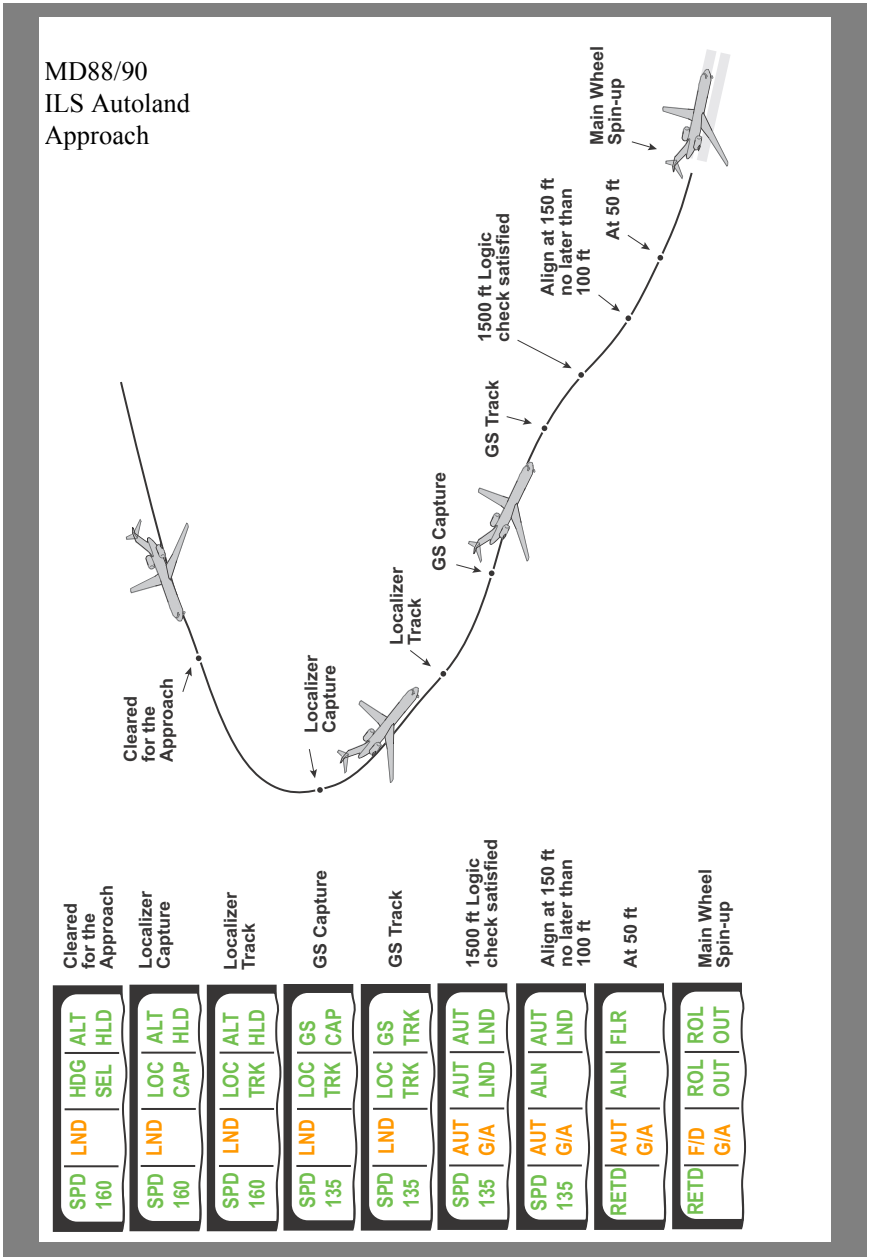
ILS Autoland Approach FMA Progression



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ILS CAT II or SA CAT II Approaches

Captain must conduct the approach.

Recommended configuration is flaps 40. This provides a 1° lower pitch attitude than 28.

Use landing/strobe lights and windshield wipers as appropriate.

A CAT II approach will end in an autoland or go around.

For inoperative equipment, refer to the QRH, Non-Normal Ops Info tab, ILS Approach Equipment Requirements.

For any inoperative ground based equipment, refer to the Airway Manual, Ops Specs, IAP.

Note: Approach may continue to DA(H) if established on the final segment and the controlling RVR goes below minimums. Specific foreign country exceptions may apply. For further information, refer to the Airway Manual, Ops Specs, IAP.

Approaches must be flown using autoland procedures.

Maximum reported wind component to initiate approach and land:

25 knots headwind, 15 knots crosswind, 10 knots tailwind

Airport diagram/SMGCS..... Review

The First Officer should have the applicable chart out and available for taxi assistance.

FMS approach procedure..... Select and verify

Select the approach procedure on the ARRIVALS page. Verify FMS LEGS page waypoints and altitude constraints match the charted approach.

Flight and nav instruments..... Set

Tune and identify the frequency for the selected approach.

Set the ILS frequency and front course.

Minimums..... Set

Note: Minimums for RVR 1600 approaches may be set to the lowest charted minimums, but no lower than 100 feet DA(H)

RA Authorized:

Set radio altimeter bug to published RA

Set baro altimeter bug to airport elevation

RA Not Authorized:

Set radio altimeter to OFF

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Set baro altimeter bug to published DA

IM required

DA is determined by the IM or the first officer's baro altimeter, whichever occurs first.

Marker beacon audio (RA Not Authorized)..... ON

Autobrakes.....Recommended

Callouts..... Review

Call “ALIGN” when ALN appears in the FMA roll window.

FMA..... Review

See FCTM, Flight Pattern Profiles, ILS Autoland for FMA progression.

At approximately 1500 feet RA, confirm AUT LND appears in the FMA roll and pitch windows.

No later than 100 feet RA, confirm ALN in the FMA roll window.

At 50 feet RA, confirm FLR in the FMA pitch window.

At 50 feet RA, confirm RETD in the FMA throttle window.

At main wheel spin-up, confirm ROL OUT in the FMA roll and pitch windows.

When cleared for the approach:

AUTO LAND..... Select

One pilot must be in ARC or ROSE mode to verify capture of the correct localizer course than may return to the ND MAP display. After localizer capture, the expanded localizer on the PFD may be used.

Once the autoland has been armed and both the localizer and glideslope are in the track mode (LND, LOC/TRK, GS/TRK) the autoland may be disengaged by accomplishing any of the following:

- Disengage the autopilot
- Push the TOGA button(s)
- Detune the ILS frequency

Select when established on a published inbound segment of the approach or when on a final approach course intercept heading. Adhere to all published step down fix altitudes located outside the final approach segment.

No later than 1,000 feet AGL:

Missed approach altitude.....Set

Set lowest initial level off altitude on missed approach procedure. Confirm bank angle and heading on the MCP.

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Execute a Missed Approach for any of the following:

- Criteria listed in the Airway Manual, Ops Specs, IAP
- In IMC, a navigation radio or flight instrument failure occurs which affects the ability to safely complete the approach
- In IMC, full scale deflection of the localizer or glide slope
- In IMC, when the navigation instruments show significant disagreement.

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ILS CAT III Approaches

Captain must conduct the approach.

Recommended configuration is flaps 40. This provides a 1° lower pitch attitude than 28.

Use landing/strobe lights and windshield wipers as appropriate.

A CAT III approach will end in an autoland or go around.

For inoperative equipment, refer to the QRH, Non-Normal Ops Info tab, ILS Approach Equipment Requirements.

For any inoperative ground based equipment, refer to the Airway Manual, Ops Specs, IAP.

Note: If the aircraft is established on the final approach segment and the controlling RVR decreases below the authorized minima, the approach may not continue to DA(H).

Approaches must be flown using autoland procedures.

Maximum reported wind component to initiate approach and land:

25 knots headwind, 15 knots crosswind, 10 knots tailwind

Airport diagram/SMGCS..... Review

The First Officer should have the applicable chart out and available for taxi assistance.

FMS approach procedure..... Select and verify

Select the approach procedure on the ARRIVALS page. Verify FMS LEGS page waypoints and altitude constraints match the charted approach.

Flight and nav instruments..... Set

Tune and identify the frequency for the selected approach.

Set the ILS frequency and front course.

Minimums..... Set

Set radio altimeter bug to 50 feet.

Set baro altimeter bug to airport elevation.

Autobrakes.....Required, if operable

Callouts..... Review

Call “ALIGN” when ALN appears in the FMA roll window.

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FMA..... Review

See FCTM, Flight Pattern Profiles, ILS Autoland for FMA progression.

At approximately 1500 feet RA, confirm AUT LND appears in the FMA roll and pitch windows.

No later than 100 feet RA, confirm ALN in the FMA roll window.

At 50 feet RA, confirm FLR in the FMA pitch window.

At 50 feet RA, confirm RETD in the FMA throttle window.

At main wheel spin-up, confirm ROL OUT in the FMA roll and pitch windows.

When cleared for the approach:

AUTO LAND..... Select

One pilot must be in ARC or ROSE mode to verify capture of the correct localizer course than may return to the ND MAP display. After localizer capture, the expanded localizer on the PFD may be used.

Once the autoland has been armed and both the localizer and glideslope are in the track mode (LND, LOC/TRK, GS/TRK) the autoland may be disengaged by accomplishing any of the following:

- Disengage the autopilot
- Push the TOGA button(s)
- Detune the ILS frequency

Select when established on a published inbound segment of the approach or when on a final approach course intercept heading. Adhere to all published step down fix altitudes located outside the final approach segment.

No later than 1,000 feet AGL:

Missed approach altitude.....Set

Set lowest initial level off altitude on missed approach procedure. Confirm bank angle and heading on the MCP.

Execute a Missed Approach for any of the following:

- Criteria listed in Airway Manual, Ops Specs, IAP, or
- In IMC, a navigation radio or flight instrument failure occurs which affects the ability to safely complete the approach, or
- In IMC, full scale deflection of the localizer or glide slope, or
- In IMC, when the navigation instruments show significant disagreement.

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Autoland

The pilots should monitor the quality of the approach, flare, and landing, including speedbrake deployment and autobrake application.

When established on the glideslope and no later than 1,000 feet AGL, set the missed approach altitude in the altitude window of the MCP.

Normal autoland operations should not require pilot intervention. However, pilot intervention should be anticipated in the event inadequate aircraft performance is suspected, or when an automatic landing cannot be safely accomplished in the touchdown zone. Guard the controls on approach through landing and be prepared to take over manually, if required.

If the AUTOLAND mode is engaged, and the dual-input logic is satisfied, the FMA will annunciate AUT LND in the roll and pitch windows below 1,500 feet radio altitude. If an autoland annunciation changes or system fault occurs, do not continue the approach unless suitable visual reference with the runway environment is established. During an autoland with crosswind conditions, the runway alignment maneuver uses forward slip to reduce the crab angle of the airplane at touchdown. Alignment begins at 150 feet radio altitude. The maneuver is accomplished primarily by the rudder axis using the parallel rudder servo with primary guidance for the rudder axis alignment derived from runway heading (CRS) error. The airplane is aligned to within 1.5° upwind of the runway heading for touchdown with a bank angle to oppose the turning moment generated by the rudder displacement (cross control). Both the aileron and rudder control systems receive localizer commands during the ALIGN mode to maintain the runway centerline. Roll control for the forward slip maneuver is limited to 5 ± 1° at touchdown. After main wheel spin up has occurred, the flight director provides steering commands to maintain runway alignment. The Autopilot maintains runway alignment with nosewheel steering for 5 seconds, then the Autopilot disengages. The Autothrottles disconnect when the thrust reversers are engaged.

Decision Altitude or Height - DA(H)

A Decision Altitude or Height is a specified altitude or height in an ILS/LDA (with GS) where a missed approach must be initiated if the required visual reference to continue the approach has not been established. The “Altitude” value is measured by a barometric altimeter and is the determining factor for minima for Category I approaches. If using ILS mode (not Autoland), the autopilot must be disengaged no later than DA.

For most Category II and all Category III approaches, the Decision Height is the controlling minima and the altitude value specified is advisory. A Decision Height is usually based on a specified radio altitude above the terrain on the final approach or touchdown zone.

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On radio altimeter not authorized (RA NOT AUTH) CAT II approaches, the minimums are based on a DA (barometric altitude) rather than a DH (height above the terrain).

Do not continue the approach below DA(H) unless the aircraft is in a position from which a normal approach to the runway of intended landing can be made and suitable visual reference can be maintained. Upon arrival at DA(H), or any time thereafter, if any of the above requirements are not met, immediately execute the missed approach procedure. When visual contact with the runway is established, maintain the glideslope to the flare. Do not descend below the visual glide path.

Descent Below Decision Altitude or Height - DA(H)

Refer to Airway Manual, Ops Specs, IAP, CAT I Approach Requirements (Precision & Non-precision), Descent Below DA(H)/MDA.

Low Visibility Approaches

A working knowledge of approach lighting systems and regulations as they apply to the required visual references is essential to safe and successful low visibility approaches. A review of the approach and runway lighting systems available during the approach briefing is recommended as the pilot has only a few seconds to identify the lights required to continue the approach. For all low visibility approaches, a review of the airport diagram, SMGCS chart (if available), expected runway exit, runway remaining lighting, and expected taxi route during the approach briefing is recommended.

RVR

Refer to Airway Manual, Ops Specs, IAP, CAT I Approach Requirements (Precision & Non-precision).

Visual References

Refer to Airway Manual, Ops Specs, IAP, CAT I Approach Requirements (Precision & Non-precision), Descent Below DA(H)/MDA.

Category III operations apply a DH of 50 feet and requires that the runway touchdown zone be clearly visible. If not, execute an immediate missed approach.

Category II and III Systems Requirements

System requirements described in this section do not include all of the systems and equipment required for each type of operation. Reference the Airway Manual, Ops Specs, IAP, CAT II Approach Requirements and CAT III Approach Requirements; QRH, NNOI.1; or MDM for specific systems and equipment needed for Category II and Category III operations.

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Category II and III Operations

Category II and III operations are based on an approach to touchdown using the automatic landing system.

During the approach, touchdown, and landing, the first officer's primary duty is to monitor the instruments and advise the captain of the approach progress. The captain is primarily responsible for acquiring the runway visually and must have visual contact with the threshold environment (Cat II) or touchdown zone, TDZ lights (CAT III) to continue below DH.

Procedures for Category II and Category III approaches are similar, except, the call out sequence of “approaching minimums”, “minimums,” and “ALIGN” will vary according to Minimums of the approach flown.

AT 1,500 feet the autoland system goes through a logic check. If the system fails the logic check, LND will flash in the FMA arm window. Ensure AUT G/A or F/D G/A appears in the FMA arm window. If automatic go-around logic is not satisfied, the FMA arm window will annunciate F/D G/A instead of AUT G/A. The approach may continue with either AUT G/A or F/D G/A annunciated in the arm window. Ensure AUT LND appears in the FMA roll and pitch windows. At Approximately 150 feet AGL RA ensure FMA roll window displays ALN. Align mode is annunciated at approximately 150 feet AGL and must be annunciated by 100 feet AGL.

Note: A go-around executed at DH may result in the aircraft touching down on the runway. Continue the go-around if this occurs.

Note: Selecting TO/GA with F/D G/A annunciated on the FMA will result in the autopilot disengaging. The missed approach must be flown manually.

At or below decision height, the F/O should monitor localizer/runway symbol on PFD for deviations from centerline. After touchdown the AUT G/A mode is disarmed, and F/D G/A is armed and available for 20 seconds. Autopilot rudder control will maintain runway track for 5 seconds after nosewheel touchdown, then the autopilot will automatically disengage. Autothrottles disconnect when reverse thrust is applied. After the autopilot disengages, the roll and pitch windows will revert to HDG HLD and ALT HLD. On rollout, F/O will give guidance using the PFD expanded localizer to runway centerline lighting:

- 3,000 feet remaining - centerline lights alternate red and white
- 2,000 feet remaining - runway edge lights become amber
- 1,000 feet remaining - centerline lights become all red.

After landing, the F/O should assist the captain in taxiway identification using the 10-9 page or SMGCS chart, as appropriate, and a safe taxi speed should be maintained.

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Autoland Capabilities

Refer to the applicable Vol. 1 limitations for AFDS limitations and a description of demonstrated autoland capabilities.

Note: For low visibility autoland use flaps 28 or 40, 40 is recommended

Note: Autoland should not be attempted unless the final approach course path is aligned with the runway centerline. If the localizer beam is offset from the centerline the AFDS may cause the aircraft to depart the runway.

Fail Operational

The MD-88/90 aircraft is not a fail operational aircraft.

ILS Performance

Most ILS installations are subject to signal interference by either surface vehicles or aircraft. To prevent this interference, ILS critical areas are established near each localizer and glideslope antenna. In the United States, vehicle and aircraft operations in these critical areas are restricted any time the weather is reported less than 800 foot ceiling and/or visibility is 2 miles (3200m) or less.

Flight inspections of ILS facilities do not necessarily include ILS beam performance inside the runway threshold or along the runway unless the ILS is used for Category II or III approaches. For this reason, the ILS beam quality may vary and autolands performed from a Category I approach at these facilities should be closely monitored.

ILS critical areas are usually not protected when the weather is above 800 foot ceiling and/or 2 statute miles visibility. As a result, ILS beam bends may occur because of vehicle or aircraft interference. Sudden and unexpected flight control movements may occur at a very low altitude or during the landing and rollout when the autopilot attempts to follow the beam bends. At ILS facilities where critical areas are not protected, be alert for this possibility and guard the flight controls (control wheel, rudder pedals, and throttles) throughout automatic approaches and landings. Be prepared to disengage the autopilot and manually land or go-around.

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Autolands on Contaminated Runways

The ROLLOUT mode performance cannot be assured when used on contaminated runways. The ROLLOUT mode relies on a combination of aerodynamic rudder control, nose wheel steering, and main gear tracking to maintain the runway centerline using localizer signals for guidance. On a contaminated runway, nose wheel steering and main gear tracking effectiveness, and therefore aircraft directional control capability, is reduced. To determine the maximum crosswind, use the most restrictive of the autoland crosswind limitation, or during low visibility approaches, the maximum crosswind authorized by the controlling regulatory agency.

Refer to Vol. 1, SP.16, Guidelines for Takeoff on Contaminated Runways or Landing with Braking Action Less than Good.

If an autoland is accomplished on a contaminated runway, the pilot must be prepared to disengage the autopilot and take over manually should ROLLOUT directional control become inadequate.

Transition to Manual Approach or Landing

A transition from an autopilot coupled Category 1 ILS approach to a manual approach can be accomplished anytime during the approach. Ensure visual cues are sufficient prior to disengaging the autopilot. After autopilot disengages, continue to keep the FD in the crosscheck and gradually transition to a visual landing. Anticipate the effect of existing crosswinds on the final portion of the approach and landing.

During the transition, inadvertently removing the crosswind correction established by the autopilot may allow the aircraft to drift off the centerline. Consideration should be given to using autoland during low visibility approaches above CAT II/III minimums.

Intercepting Glideslope from Above

The following technique may be used for ILS approaches.

Normally the ILS profile is depicted with the aircraft intercepting the glideslope from below in a level flight attitude. However, there are occasions when flight crews are cleared for an ILS approach when they are above the G/S. In this case, there should be an attempt to capture the G/S prior to the FAF. The map display can be used to maintain awareness of distance to go to the FAF. The use of autopilot is also recommended.

Note: Before intercepting the G/S from above, the flight crew must ensure that the localizer is captured before descending below the cleared altitude or the FAF altitude.

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The following technique will help the crew intercept the G/S safely and establish stabilized approach criteria by 1,000 feet AFE:

- Select ILS /LND on the MCP and verify that the desired mode is armed.
- Establish final landing configuration and set the missed approach altitude no lower than 1,000 feet AFE.
- Select the V/S mode and set -1,000 to -1,500 fpm to achieve G/S capture and be stabilized for the approach by 1,000 feet AFE.
- Use of the green altitude range arc may assist in establishing the correct rate of descent.

Monitor the rate of descent and airspeed to avoid exceeding flap placard speeds. At G/S capture observe the flight mode annunciations for correct modes and monitor G/S deviation. After G/S capture, continue with normal procedures.

Note: If the glideslope is not captured or the approach not stabilized by 1,000 feet AFE, initiate a go-around. Because of glideslope capture criteria, the glideslope should be captured and stabilized approach criteria should be established by 1,000 feet AFE on every approach.

Delayed Flap Approach

If conditions warrant, the final flap selection may be delayed to conserve fuel or to accommodate speed requests by air traffic control.

Intercept the glideslope at assigned speed. The thrust required to descend on the glideslope may be near idle. Establish final configuration so that flaps are fully extended by 1,000 feet AFE, allow the speed to bleed off to the final approach speed, and then adjust thrust to maintain it. Complete the Landing checklist.

At all times comply with stabilized approach criteria.

Faults

Autoland must be used for all CAT II/III approaches. All CAT II/III approaches must end in an automatic landing in the touchdown zone or a go-around. Due to the close proximity with the ground when minimums and the Autoland flare and landing functions are occurring, it is important that the F/O be familiar with the Autoland sequence and possible malfunctions. This will allow for quick recognition of a problem and the timely execution of a go-around. Some possible faults are:

- Flashing LND on FMA
- No ALN by 100 feet AFE
- No FLR at 50 feet AFE
- Improper runway line up (Offset Rising RWY symbol).

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Raw Data - (No Flight Director)

ILS deviation is displayed on the PFD. ILS deviation may also be displayed on the navigation display by selecting ARC or ROSE mode on the EFIS Mode selector. Set the VOR/ADF to display appropriate pointers on the ND. Continue to crosscheck the map display against the PFD raw data. Begin the turn to the inbound localizer heading at the first movement of the course deviation bar.

After course intercept, the track line and read-out on the navigation display may be used to assist in applying proper drift correction and maintaining desired course. Bank as needed to keep the course deviation bar centered and the track line over the course line. This method automatically corrects for wind drift with very little reference to actual heading required.

Large bank angles are rarely required while tracking inbound on the localizer. Use 5° to 10° of bank angle.

When the glideslope pointer begins to move (glideslope alive), or at approximately 1800-2000 AFE if already tracking the glide slope, lower the landing gear, extend flaps, and establish the final approach speed. On final approach, maintain appropriate airspeed. Check altitude and time crossing the FAF. To stabilize on the final approach speed as early as possible, it is necessary to exercise precise speed control during the glideslope intercept phase of the approach. The rate of descent varies with the glideslope angle and ground speed. Expeditious and smooth corrections should be made based on the ILS course and glideslope indications. Apply corrections at approximately the same rate and amount as the flight path deviations.

The missed approach procedure is the same as a normal missed approach. Flight Director guidance appears if TO/ GA is selected. Refer to Go-Around and Missed Approach - All Approaches, this chapter.

ILS PRM Approach

PRM Procedures

Refer to the Vol. 1, NOI, ILS Precision Runway Monitor (PRM) Considerations.

Refer to Airport Specific Attention All Users Page.

- Use ILS approach procedures. The use of the autopilot is recommended.
- Recognize the importance of flying a precise approach. Maintaining localizer centerline is especially important during ILS PRM approaches due to the distance between parallel runway centerlines.

PRM Breakout Maneuvers: General

When breakout instructions are issued, it is important to initiate a turn without delay. This is accomplished more quickly by selecting the AP and FD off and hand flying the turn. The bank angle should not exceed 15º.

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Transition to a smooth climb or descent as instructed. Descents need not exceed 1,000 fpm. Recognize if the aircraft is already tracking the glideslope (at approximately 800 fpm) that little or no change of pitch or rate of descent may be required.

Phraseology

TRAFFIC ALERT: If an aircraft enters the NO TRANSGRESSION ZONE (NTZ), the controller will breakout the threatened aircraft on the adjacent approach. The phraseology for the breakout will be:
"TRAFFIC ALERT (aircraft call sign), TURN (left/right) IMMEDIATELY HEADING (degrees). CLIMB/DESCEND AND MAINTAIN (altitude)."

Note: If ATC Breakout instructions coincide with TCAS RA, follow the vertical guidance of the RA and the lateral guidance directed by ATC.

PRM Breakout Maneuver

Note: All "Breakouts" must be hand flown.

Pilot Flying	Pilot Monitoring
If ATC call "Traffic Alert" during the PRM approach:	
A/P - Disengage	F/D (both) - OFF
Maneuver as directed by ATC **Note:** If ATC "breakout" instructions coincide with a TCAS RA, follow the vertical guidance of the RA and the lateral guidance directed by ATC. **Note:** If descending, vertical speed should not exceed 1,000 FPM.	Communicate with ATC as required.
	When established on the "breakout" heading: • F/D (both) - ON
When "breakout" is complete, reset automation to appropriate level.	

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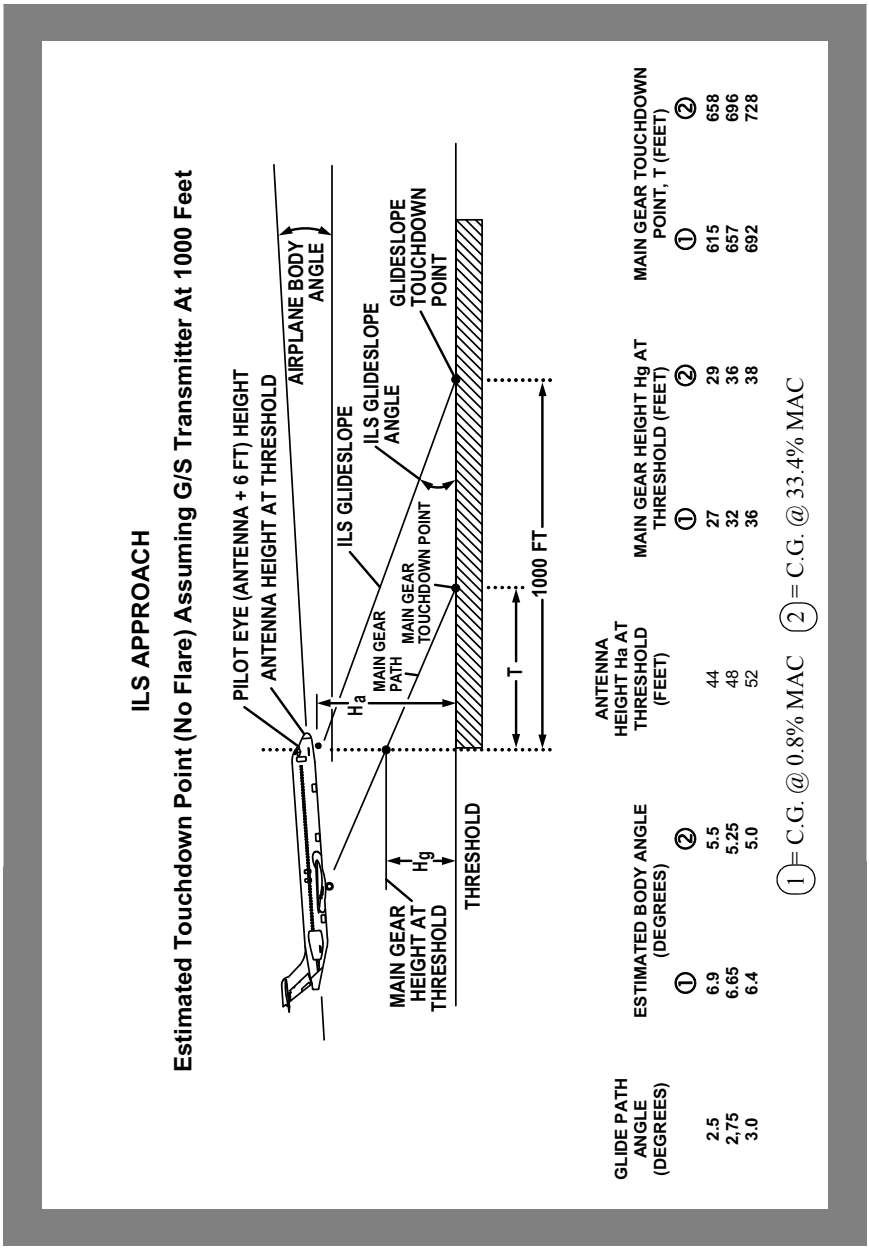
ILS Approach - Landing Geometry

MD-88

Approach and Landing - Flaps 28 (1.3 Vs)



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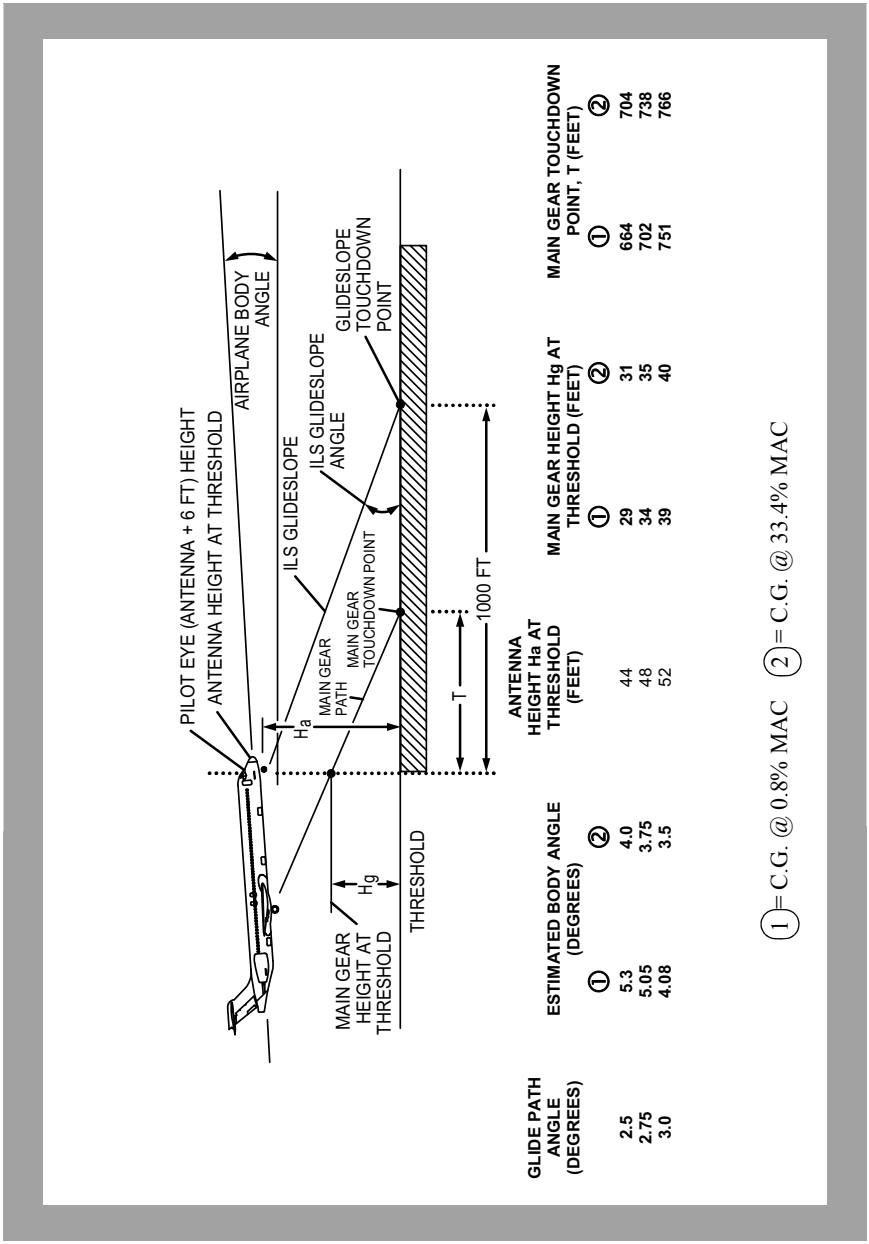
MD-88

Approach and Landing - Flaps 40 (1.3 Vs)



GLIDE PATH ANGLE (DEGREES)	ESTIMATED BODY ANGLE (DEGREES)		ANTENNA HEIGHT Ha AT THRESHOLD (FEET)	MAIN GEAR HEIGHT Hg AT THRESHOLD (FEET)		MAIN GEAR TOUCHDOWN POINT, T (FEET)	
	①	②		①	②	①	②
2.5	5.3	4.0	44	29	31	664	704
2.75	5.05	3.75	48	34	35	702	738
3.0	4.08	3.5	52	39	40	751	766

① = C.G. @ 0.8% MAC ② = C.G. @ 33.4% MAC

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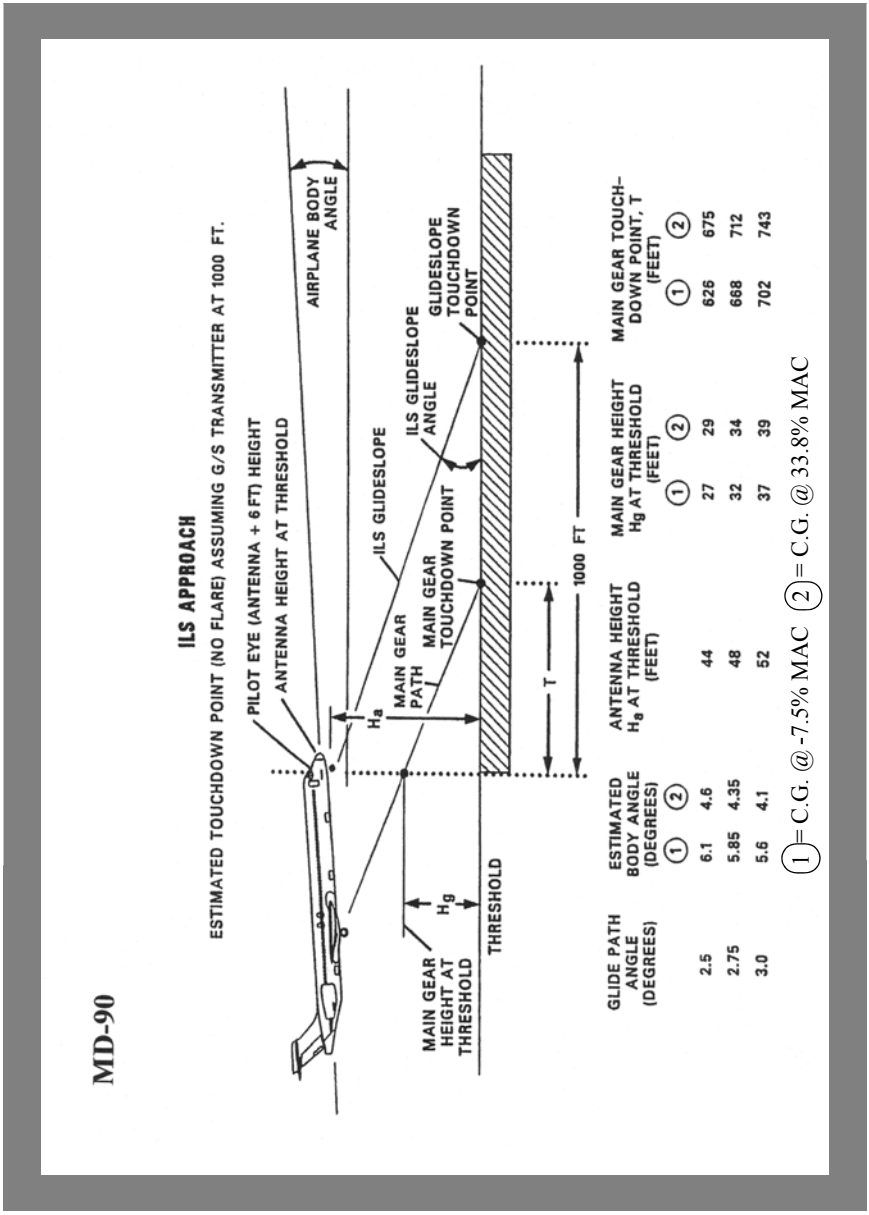
MD-90
Approach and Landing - Flaps 28 (1.3 Vs)



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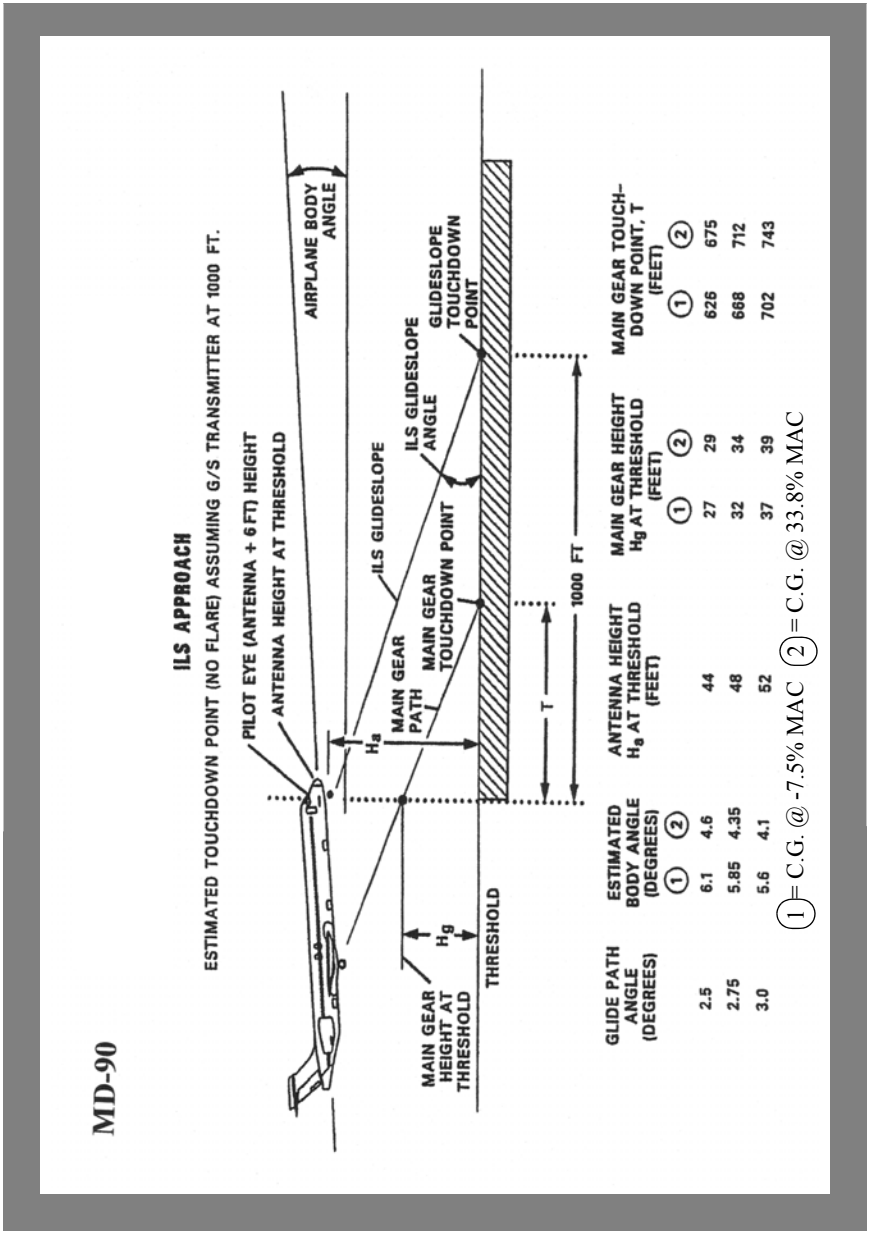
MD-90

Approach and Landing - Flaps 40 (1.3 Vs)



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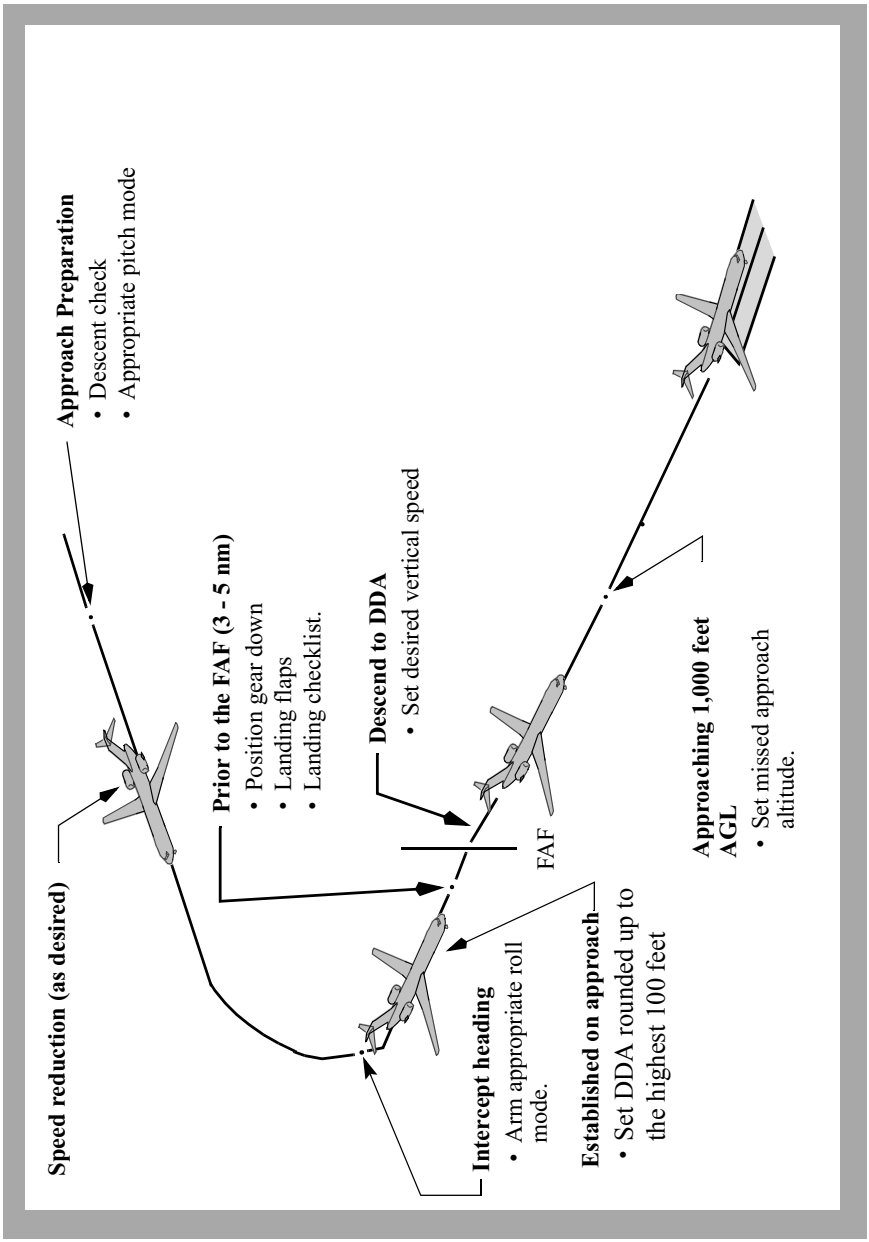
Non - ILS Instrument Approaches

Instrument Approach Using V/S Profile



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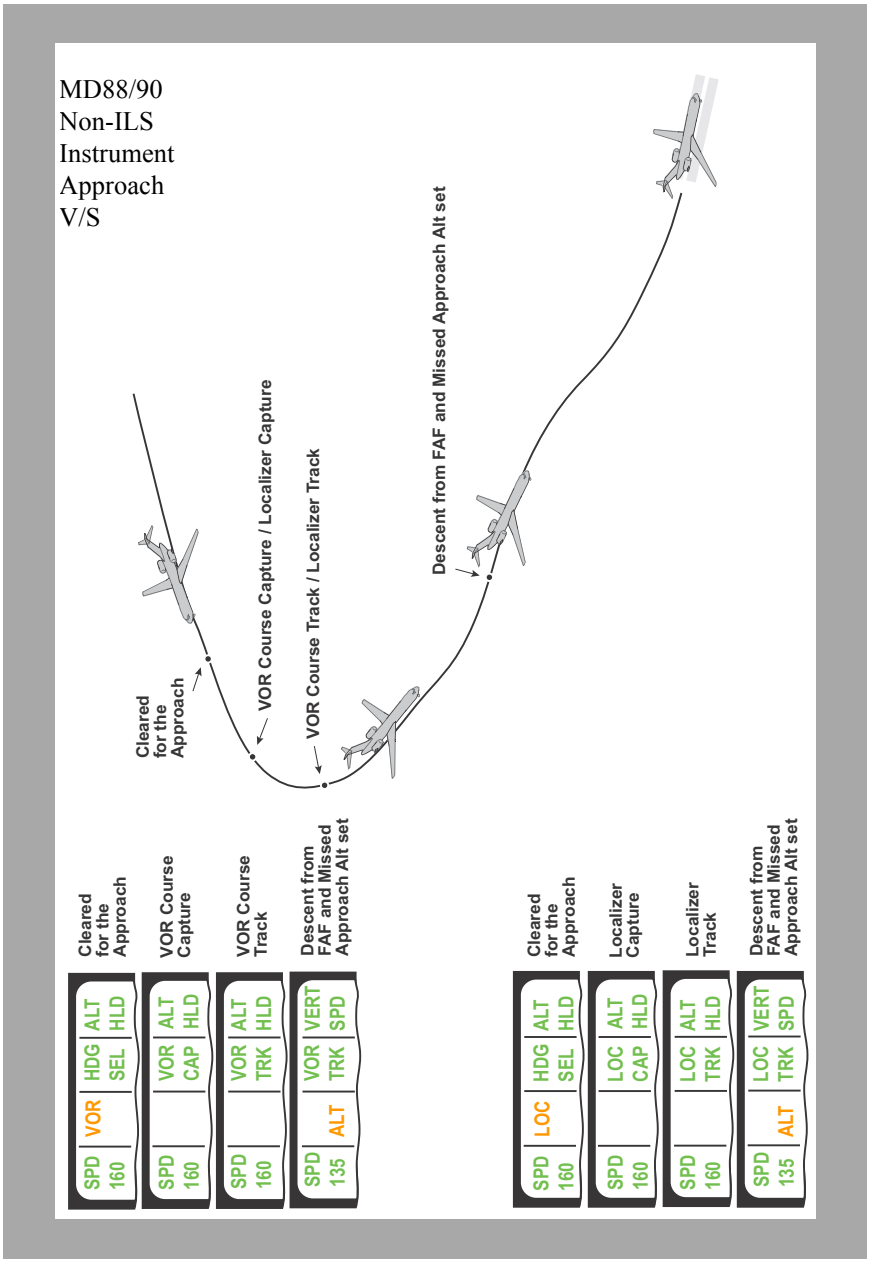
Non-ILS Instrument Approach V/S FMA Progression



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Non-ILS Approach Considerations

Use all suitable electronic and visual systems to assist in identifying the airport and landing runway.

Approach and landing should be planned to maintain minimum drag configurations as long as possible, safety and conditions permitting, while still meeting the stabilized approach requirements.

Plan to configure the aircraft 3-5 NM prior to the FAF.

If in IMC, use of the autopilot is required until visual contact with the runway can be maintained or upon arrival at the DA/DDA, whichever occurs first.

NAV may be used to track the final approach course, but the appropriate roll mode (ILS, HDG SEL, or VOR/LOC) must be selected no later than the final approach fix or segment.

NAVAID Setup

Raw data must be monitored throughout the approach.

Both pilots should be on the navigation radio frequency that provides final approach information no later than the final approach fix or segment. If necessary, the second radio can be tuned to a different frequency to provide information for crossing altitudes.

Altitude and instruments should be crosschecked when crossing the FAF, or FAP, for the approach being flown.

All available NAVAIDs must be identified and used to ensure proper identification of the runway and airport.

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ILS (GS Out) or LDA (without GS) or LOC or VOR Approaches

Autopilot…..…….....…….required in IMC

Disconnect the autopilot no later than 50 feet below the MDA.

FMS approach procedure…….....…….select and verify

Select the approach procedure on the ARRIVALS page. Verify FMS LEGS page waypoints and altitude constraints match the charted approach.

Flight and nav instruments…….....…….…….set

Tune and identify the frequency for the selected approach.

For an ILS (GS Out) or LDA (without GS) or LOC approach set the ILS frequency and front course.

For a VOR approach set the VOR frequency and course.

Minimums…….....……set DDA

Derived Decision Altitude (DDA) is the published MDA plus 50 feet.

Set the baro altimeter bug to DDA.

Raw data and VTK ERROR…….....…….…….monitor

For an ILS (GS Out) or LDA (without GS) or LOC approach one pilot must be in ARC or ROSE mode to verify capture of the correct localizer course than may return to the ND MAP display. After localizer capture, the expanded localizer on the PFD may be used.

For a VOR approach one pilot must be in ARC or ROSE to verify capture of the VOR course. One pilot must remain in ARC or ROSE for the approach. The RDMI #1 selector switch to VOR may be used as a backup to ARC or ROSE. One pilot should use the ND MAP display for situational awareness.

FMS PROGRESS page 2/2 may be displayed to monitor XTK and VTK ERROR.

When cleared for the approach:

VOR/LOC or NAV…….…….....…….…….select

VOR/LOC or NAV may be selected for the approach, but VOR/LOC is required from the FAF inbound.

Note: If needed, HDG SEL may be used to track the VOR course through the cone of confusion.

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When established on a published segment of the approach and level at FAF altitude or vectored to a final approach course intercept heading and level at FAF altitude:

MCP altitude…….…….....……….....set

Set the DDA rounded up to the next highest 100 feet.

For approaches with step-down fixes inside the FAF, do not set the step-down fix altitude.

When at descent point:

VERT SPD…….....…….…….select

VNAV may be used up to the FAF.

At the FAF use the VERT SPD pitch wheel to control descent rate inside the FAF. Use the published descent rate. If there is no published descent rate, use an initial descent rate of 800fpm. This will approximate a 3° glidepath.

Monitor the "green arc" on the ND MAP display.

No later than 1000 feet:

Missed approach altitude…….....…….set

Set lowest initial level off altitude from the published missed approach. Confirm bank angle and heading on the MCP.

No later than 100 feet below DDA:

Autopilot…….....…….…….disconnect

Execute a Missed Approach for any of the following:

- Criteria listed in Airway Manual, Ops Specs, IAP, or
- In IMC, a navigation radio or flight instrument failure occurs which affects the ability to safely complete the approach, or
- In IMC, full scale deflection of the localizer during an ILS (GS Out) or LDA (without GS) or LOC approach, or
- In IMC, actual course deviates from published inbound course by more than 10° during a VOR approach, or
- In IMC, when the navigation instruments show significant disagreement.

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LOC (BACK CRS) or NDB Approach Guide

HDG SEL & VERT SPD

Autopilot…….....…….required in IMC

Disconnect the autopilot no later than 50 feet below the MDA.

FMS approach procedure……...……. …….select and verify

For a LOC (BACK CRS) select the approach procedure on the ARRIVALS page. Verify FMS LEGS page waypoints and altitude constraints match the charted approach.

For an NDB approach select an underlying straight-in approach or extend runway centerline for situational awareness.

Flight and nav instruments…….....…….….set

Tune and identify the frequency for the selected approach.

For a LOC (BACK CRS) approach set the ILS frequency and front course on the CDI to compensate for reverse sensing. Ignore any glide slope information.

For an NDB approach set the NDB frequency.

Minimums…….....……set DDA

Derived Decision Altitude (DDA) is the published MDA plus 50 feet.

Set the baro altimeter bug to DDA.

Raw data and VTK ERROR…….....…….monitor

For a LOC (BACK CRS) approach one pilot must be in ARC or ROSE mode.

The expanded localizer on the PFD is not directional. The PM should use the ND MAP display for situational awareness.

For an NDB approach select ADF to ON on the EFIS control panel. This will display the ADF needle on the ND in the ARC, ROSE, or MAP modes and raw data can be monitored in any of these modes. Select the RDMI #1 selector switch to ADF to display course information on the RDMI. One pilot should use the ND MAP display for situational awareness.

FMS PROGRESS page 2/2 may be displayed to monitor XTK and VTK ERROR.

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When cleared for the approach:

CAUTION: Automatic flight guidance and autopilot tracking of the back course are not available. Do not arm ILS or VOR/LOC.

HDG SEL or NAV …….....…….select

HDG SEL or NAV may be selected for the approach, but HDG SEL is required from the FAF inbound.

When established on a published segment of the approach and level at FAF altitude or vectored to a final approach course intercept heading and level at FAF altitude:

MCP altitude…….....…….....set

Set the DDA rounded up to the next highest 100 feet.

For approaches with step-down fixes inside the FAF, do not set the step-down fix altitude.

When at descent point:

VERT SPD…….....…….select

VNAV may be used up to the FAF.

At the FAF use the VERT SPD pitch wheel to control descent rate inside the FAF. Use the published descent rate. If there is no published descent rate, use an initial descent rate of 800fpm. This will approximate a 3° glidepath.

Monitor the “green arc” on the ND MAP display.

No later than 1,000 feet:

Missed approach altitude…….....…….set

Set lowest initial level off altitude from the published missed approach. Confirm bank angle and heading on the MCP.

No later than 100 feet below DDA:

Autopilot…….....…….disconnect

Execute a Missed Approach for any of the following:

- Criteria listed in Airway Manual, Ops Specs, IAP, or
- In IMC, a navigation radio or flight instrument failure occurs which affects the ability to safely complete the approach, or
- In IMC, full scale deflection of the localizer for a LOC (BACK CRS) approach, or
- In IMC, actual course deviates from published inbound course by more than 10° during an NDB approach, or
- In IMC, when the navigation instruments show significant disagreement.

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General

Non-ILS approaches are defined as:

- RNAV Visual approach - a visual approach that relies on aircraft navigation equipment to align the aircraft with a visual final. The approach is selected in the FMS and flown using RNAV until reaching the visual segment.
- VOR approach
- NDB approach
- LOC, LOC (BACK CRS), LDA or similar approaches.

Note: The MD-88/90 aircraft are not currently approved for RNAV (RNP) operations.

Non-ILS approaches are normally flown using vertical speed mode to achieve a pre-computed descent rate. The Continuous Descent Final Approach (CDFA) provides a profile very similar to an ILS-type final approach segment. There is no level off during the approach so large pitch and power changes are not required. VDP calculations are also not required.

Non - ILS Instrument Approaches - General

The following sections describe methods for flying non-ILS CDFA. These methods provide a constant angle approach, which reduces exposure to crew error and CFIT accidents. These methods also make it much easier for the crew to achieve a stabilized approach to a landing once suitable visual reference to the runway environment has been established.

A typical Instrument Approach using V/S, as illustrated in the profile, assumes all preparations for the approach; such as review of the approach procedure and setting of minima and radio tuning have been completed. The procedures illustrated focus generally on crew actions and avionics systems information. The flight pattern may be modified to suit local traffic and ATC requirements.

The following discussions assume a straight-in instrument approach is being flown.

Types of Approaches

VS will be used to descend from the FAF on non-ILS approaches.

Use of the Autopilot During Approaches

Automatic flight is the required method of flying non-ILS approaches in IMC conditions.

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Raw Data Monitoring Requirements

Use all suitable electronic and visual systems for assistance. Checking raw data for correct navigation prior to commencing the approach may be accomplished by:

- Selecting ARC or ROSE on the EFIS mode selector panel and comparing the displayed raw data with the navaid symbols on the map.
- Displaying the VOR and/or ADF pointers on the map display and using them to verify your position relative to the map display.

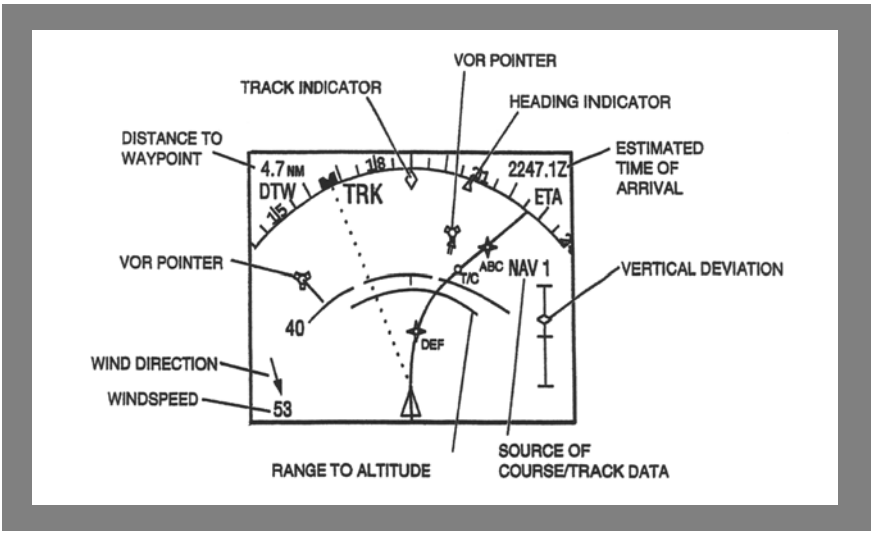
When outside the FAF, the pilot must use raw data to identify the final approach course. As long as MAP indications are normal, the pilot may use the FMS to identify step down fixes.

When at or inside the FAF, the pilot must use raw data to identify course and any step down fixes.

It is not necessary for both pilots to display raw data. See nav display set ups in this chapter for each type of non-precision approach.

Typical Navigation Display

The following diagram represents a typical navigation display with the MAP display selected.



RNAV Approaches

The aircraft is not currently authorized to conduct RNAV approaches. This section is retained for future capabilities.

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Use of NAV

To use NAV for approaches and missed approaches, a proper series of legs/waypoints that describe the approach route (and missed approach) must appear on the LEGS page. There are two methods of loading these waypoints:

Database Selection

- An approach procedure selected through the FMS ARRIVALS page provides the simplest method of selecting proper waypoints. Procedures in the database comply with obstruction clearance criteria for non-ILS approaches.
- No waypoints may be added or deleted between the FAF and the MAP.
- If the approach to be flown is not in the database, another approach having the same plan view may be selected. For example, to fly an NDB approach, an ILS procedure might be selected if the plan view (route) is identical to the NDB approach. In this case, waypoint altitudes must be checked and modified as required. When an approach is flown by this "overlay" method, raw data should be monitored throughout the approach to ensure obstacle clearance.
- If a waypoint is added to or deleted from a database procedure, FMS "on approach" logic is partially or completely disabled and the VNAV obstacle clearance integrity of the procedure may be adversely affected. If an additional waypoint reference is desired, use the FIX page and do not modify waypoints on the LEGS page.

Manual Waypoint Entry

- When no procedure is available from the FMS ARRIVALS page, manual entry of a series of waypoints may be accomplished to define the approach routing. The waypoints may be conveniently defined by using names of waypoints or navaids in the database, bearing/distance from such fixes, intersections of radials, or latitude/longitude information.
- Procedure turns and DME arcs usually cannot be manually entered (unless they can be defined by a series of waypoints). Deviation from the defined route may require use of DIRECT TO or INTC LEG TO when intercepting the inbound course. Constant monitoring of raw data during the approach is required.

  Note: Procedure turns and DME arcs may require use of HDG SEL.

NAV cannot be used to track fix or radial data displayed on the map that is not part of the active route. A navaid/waypoint and the appropriate radial may be inserted on the FIX page to create a "course" line on the map that helps to improve situational awareness. This method provide reference information on the map display only. It is not reflected on the LEGS page and cannot be tracked with NAV.

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This method should only be used when there is no opportunity to use an approach selected from the navigation database and should therefore be considered only when normal means of displaying approaches are not available. Pilots should be aware that the displayed course is an FMS-calculated course and is not raw data information.

Note: HDG SEL should be used to fly the approach ground track.

If the approach is not available in the navigation database, select the landing runway from the FMS arrivals page. Extend the centerline from the selected runway to help maintain position awareness.

Pilots should not become involved in excessive “heads down” FMS manipulation to build map displays while at low altitude. Raw data ARC or ROSE displays should be used to avoid distractions during higher workload phases of flight. Map building should be avoided below 10,000 feet AGL.

Note: The use of NAV between the FAF and the MAP is prohibited.

Non-ILS Instrument Approach Using V/S

Approach Preparations for Using V/S

Select the approach procedure from the ARRIVALS page, if available. Tune and identify appropriate navaids. If additional waypoint references are desired, use the FIX page or a waypoint may be added to the LEGS page. To enable proper NAV waypoint sequencing, select a straight-in intercept course to the FAF when being radar vectored to final approach. Set the DDA using the baro index reference knob, to ensure that if a missed approach is initiated, descent below the MDA(H) does not occur during the missed approach.

Final Approach Using V/S

Approaching intercept heading, select flaps 11or 15. When cleared to intercept or cleared approach, select NAV or other appropriate roll mode. Approaching the final approach fix and level (VNAV LVL) at the FAF altitude, set the MCP altitude window to DDA rounded up to the next highest 100 feet. Approximately 3-5 nm prior to the FAF, select gear down, adjust the speed, set flaps 28/40 and arm the spoilers.

Prior to the FAF, do the Landing checklist.

Initiate descent at the FAF or descent point. Select V/S using the pitch wheel and descend at appropriate vertical speed to arrive at the DDA at a distance from the runway to allow a normal landing profile. Initial selection of an appropriate V/S should be made considering the recommended vertical speeds that are published on the approach chart, if available. These recommended vertical speeds vary with the aircraft's ground speed on final approach. If no recommended vertical speeds are available, set approximately -700 to -800 fpm.

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When stabilized in a descent on final approach, use one of the following techniques to make small incremental changes to the resulting vertical speed to achieve a constant angle descent to minimums. There should be no level flight segment at minimums.

Several techniques may be used to achieve a constant angle path that arrives at DDA to continue a normal descent path to the runway:

- The most accurate technique is to monitor the VNAV path deviation indication on the map display or VTK ERROR on PROGRESS page 2/2 and adjust descent rate to maintain the aircraft on the appropriate path. This technique requires the path to be defined appropriately on the LEGS page and there is a RWxx, or named waypoint on the LEGS page with an altitude constraint which corresponds to approximately 50 foot threshold crossing height. When this method is used, crews must ensure compliance with each minimum altitude constraint on the final approach segment (step-down fixes).
- Using 300 feet per nm for a 3° path, determine the desired HAA which corresponds to the distance in nm from the runway end. The PM can then call out recommended altitudes as the distance to the runway changes (Example: 900 feet - 3 nm, 600 feet - 2 nm). The descent rate should be adjusted in small increments for significant deviations from the nominal path.

To prevent inadvertent altitude capture on descent from FAF do not set the missed approach altitude in the MCP until at least 300 feet below the missed approach altitude and prior to 1,000 feet AGL. Disengage the autopilot before descending below DDA minus 100 feet.

Derived Decision Altitude (DDA)

The pilot monitoring should expand the instrument scan to include outside visual cues when approaching DDA. Be prepared to land or go-around from the DDA. Do not continue the approach below DDA unless the aircraft is in a position from which a normal approach to the runway of intended landing can be made and suitable visual reference can be maintained. Upon arrival at DDA or any time thereafter, if any of the above requirements are not met, immediately execute a go-around and fly the missed approach procedure.

When suitable visual reference is established, maintain the descent path to the flare. Do not descend below the visual glide path.

Note that a normal landing cannot be completed from the published missed approach point on many instrument approaches.

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Circling Maneuver

A circling approach may be flown following an instrument approach using V/S provided the MCP altitude is set in accordance with the circling approach procedure.

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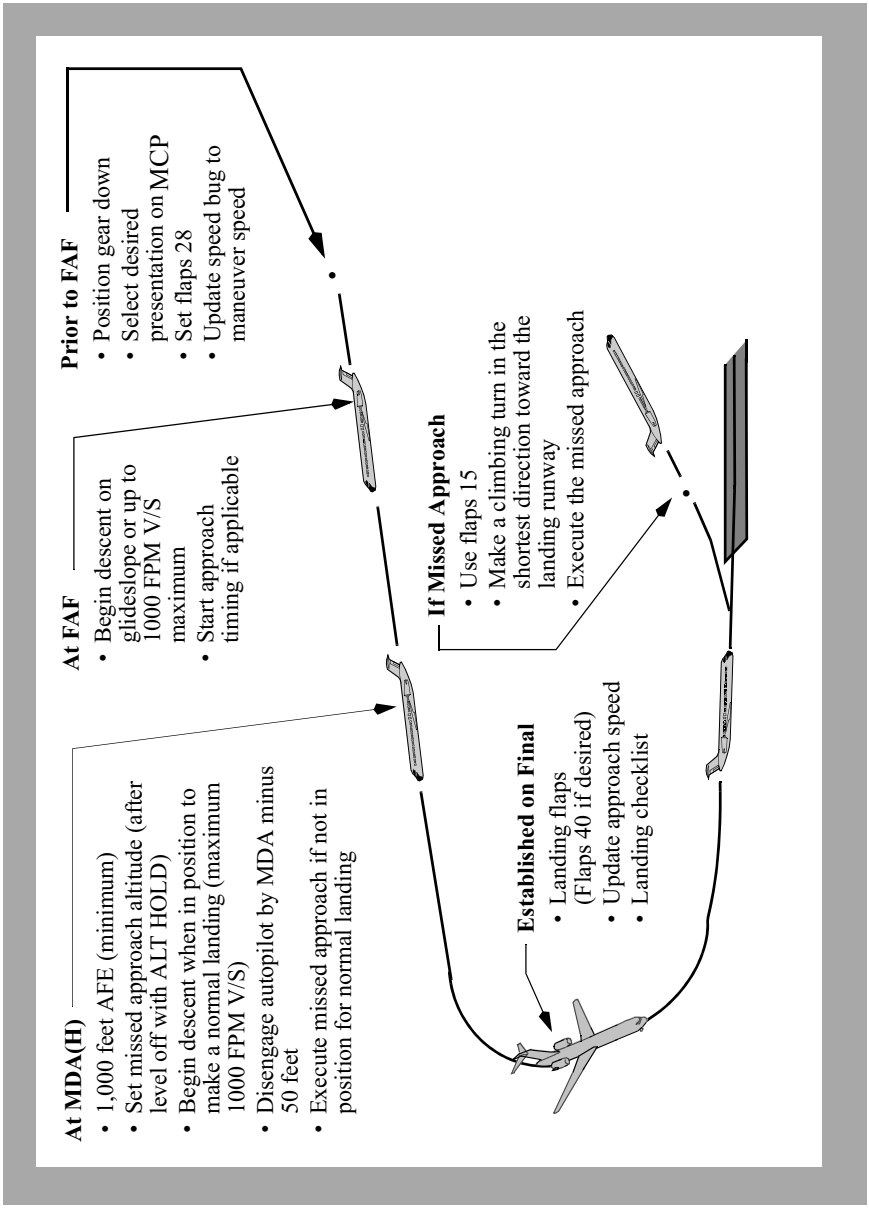
Circling Approach Profile



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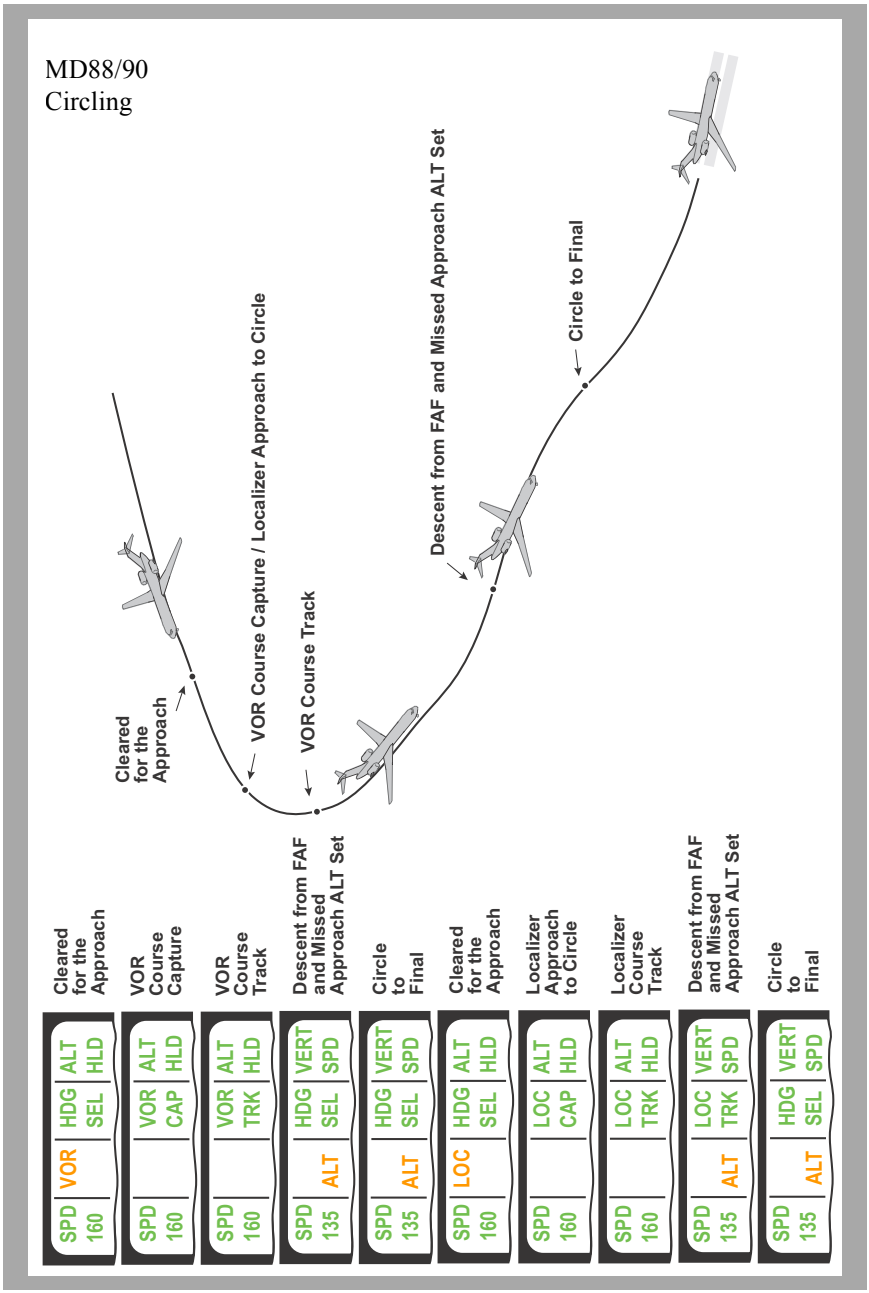
Circling FMA Progression



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Circling Maneuver - General

The following guidance supplements normal approach preparations and procedures for the type of approach to be flown.

Several flight incidents have been attributed to the difficulties in flying cross-cockpit (i.e., first officer flying a left-hand circling maneuver or the captain flying a right-hand circling maneuver). The captain should consider the direction of the circling maneuver when determining the PF assignment.

The circling maneuver is flown in the landing configuration with the Landing checklist complete. The circling maneuver is conducted in VFR conditions. Weather requirements are 1,000 foot ceiling and 3 miles visibility or Category D circling minimums, whichever is higher. Use the greater of published circle-to-land MDA or airport elevation plus 1,000 feet as the circling MDA.

The circling maneuver may be flown following any instrument approach procedure. During the instrument approach, use V/S mode to descend to the circling MDA.

Maintain MDA using ALT HOLD. Use HDG SEL for the maneuvering portion of the circling approach.

Note: If the MDA(H) does not end in “00”, set the MCP altitude to the nearest 100 feet above the MDA and circle at MCP altitude.

When in ALT HOLD at MCP altitude or the MDA and before commencing the circling maneuver, set the missed approach altitude.

To avoid overshooting final approach course, adjust the turn to final to initially aim at the inside edge of the runway threshold. Do not descend below MDA until intercepting the visual profile to the landing runway.

Disengage the autopilot no later than MDA minus 50 feet. Flight director guidance using HDG SEL and V/S may be used to maintain the descent path to the runway.

Obstruction Clearance

Obstruction clearance areas during the circling maneuver are depicted in the following figure. Circling approach minimums for both FAA and ICAO criteria are based on obstruction clearance for approach maneuvering within a defined region of airspace. For circling approaches, maximum aircraft speeds are shown on the approach plate instead of aircraft approach categories. Distances are determined by the maximum IAS during the circling maneuver and are depicted in the table following the figure.

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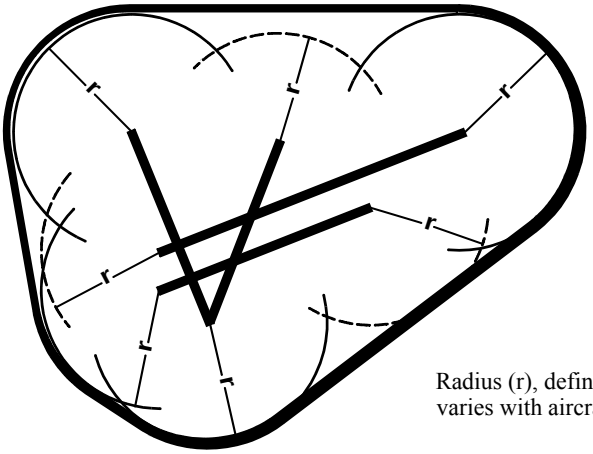

Radius (r), defining size of areas, varies with aircraft airspeed.

FAA		
Maximum IAS	**Circling Area Radius (r) from Threshold**	**Expanded Circling Area Radius (r) from Threshold**
140 knots (Cat C)	1.7 nm	2.7 nm
165 knots (Cat D)	2.3 nm	3.6 nm

ICAO	
Maximum IAS	**Circling Area Radius (r) from Threshold**
180 knots	4.2 nm
205 knots	5.28 nm

Note: Expanded circling radius is indicated by a C in the minima block of the Jeppesen chart.

Note: Adjust aircraft heading so the aircraft ground track does not exceed the obstruction clearance distance from the runway at any time during the circling maneuver.

Note: Aircraft maneuvering outside of the circling airspace do not have guaranteed obstacle clearance protection.

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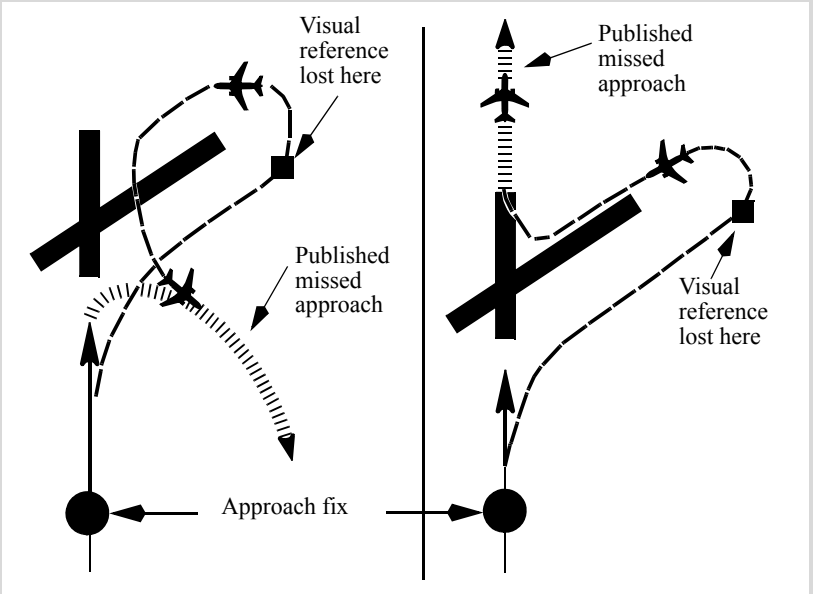
Missed Approach - Circling

If a missed approach is required at any time while circling, make a climbing turn in the shortest direction toward the landing runway. Continue the turn until established on an intercept heading to the missed approach course corresponding to the instrument approach procedure just flown. This may result in a turn greater than 180° to intercept the missed approach course. Maintain the missed approach flap setting until close-in maneuvering is completed.

Different patterns may be required to become established on the prescribed missed approach course. This depends on aircraft position at the time the missed approach is started. The following figure illustrates the maneuvering that may be required. This ensures the aircraft remains within the circling and missed approach obstruction clearance areas.



In the event that a missed approach must be accomplished from below the MDA, consideration should be given to selecting a flight path which ensures safe obstacle clearance until reaching an appropriate altitude on the specified missed approach path.

Refer to Go-Around and Missed Approach - All Approaches, this chapter.

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Visual Approach

Visual Approach - General

The recommended landing approach path is approximately 2 1/2° to 3°. Once the final approach is established, the airplane configuration remains fixed and only small adjustments to the glide path, approach speed, and trim are necessary. This results in the same approach profile under all conditions.

Downwind and Base Leg

The profile view depicts an idle, descending approach from abeam the touchdown point to arrive at a five mile final in the landing configuration at or slowing to, final approach speed. Be prepared to modify the profile to account for terrain and ATC instructions.

Plan to be at an altitude of 7000 feet AFE or lower on downwind. Abeam the touchdown point, extend the flaps to 11 and slow to 210 knots. Begin descent to 1500 feet AFE. Maintain a track parallel to the landing runway approximately 5 NM abeam.

Turn base abeam the marker, FAF, 6.4 nm DTW (Distance To Waypoint) on the ND if the runway is the active waypoint, or when the runway is 45 degrees behind the airplane. Extend the flaps to 15 and slow 180 knots.

Approaching the extended runway centerline arm the appropriate roll mode if desired, configure for landing and slow to VREF + wind additive. Complete the Landing checklist. Descent using a VASI should not be initiated until the aircraft is aligned with the runway centerline.

When flying a straight in arrival, plan to cross 30 nm from the airport at 10000 AFE and 250 knots. Cross 20 nm at 6000 AFE extend the flaps to 11 and slow to 210 knots. Cross 10 nm at 3000 AFE extend the flaps to 15 and slow to 180 knots. Configure for landing no later than 1500 AFE and slow to VREF plus wind additive.

Internal Visual Cues

Select the ILS or any approach to the intended landing runway, and make the FAF/OM the active waypoint. Set the intercept course to the selected runway inbound course. Use the cross track indication (ND and/or Progress page 2/2 XTK ERROR) to establish the desired downwind leg displacement. DTW on the ND in conjunction with the radar altimeter can be used to calculate a 3 to 1 glide path. Use Progress page 2/2 VTK ERROR to reference the vertical path to the runway. Select VERT SPD 700 to 800 FPM down to provide a flight director pitch reference. When the tip of the miniature airplane symbol is abeam the approach end of RWY symbol, the aircraft is abeam the intended point of landing. On base leg, initiate the turn to final when the XTK ERROR is approximately 1.5NM.

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Vertical Guidance On a Visual Approach

Descending prematurely below the 3:1 path or the vertical guidance on a visual approach can expose the crew to threats such as obstacles and terrain. If below a 3:1 descent profile/vertical guidance, climb to reestablish the desired descent profile/vertical guidance or execute a go-around.

Final Approach

Roll out of the turn to final on the extended runway centerline and maintain the appropriate approach speed. An altitude of approximately 300 feet AFE for each nm from the runway provides a normal approach profile. Engine thrust and elevators are the primary means to control attitude and rate of descent. Adjust thrust slowly using small increments. Sudden large thrust changes make airplane control more difficult and are indicative of an unstable approach. Stabilize the aircraft on the selected approach airspeed with an approximate rate of descent between 700 and 900 fpm on the desired glide path, in trim. Maintain stabilized approach criteria throughout the approach.

Attempt to be at 250-300 feet AFE as the closest approach light disappears from view. Disconnect the autothrottle no later than 50 feet RA. A runway aiming point slightly beyond the 1000 foot mark should result in main gear touchdown point between 1000 and 1500 feet. Main landing gear should cross the runway threshold at approximately 50 feet.

Note: Descent rates greater than 1000 fpm should be avoided.

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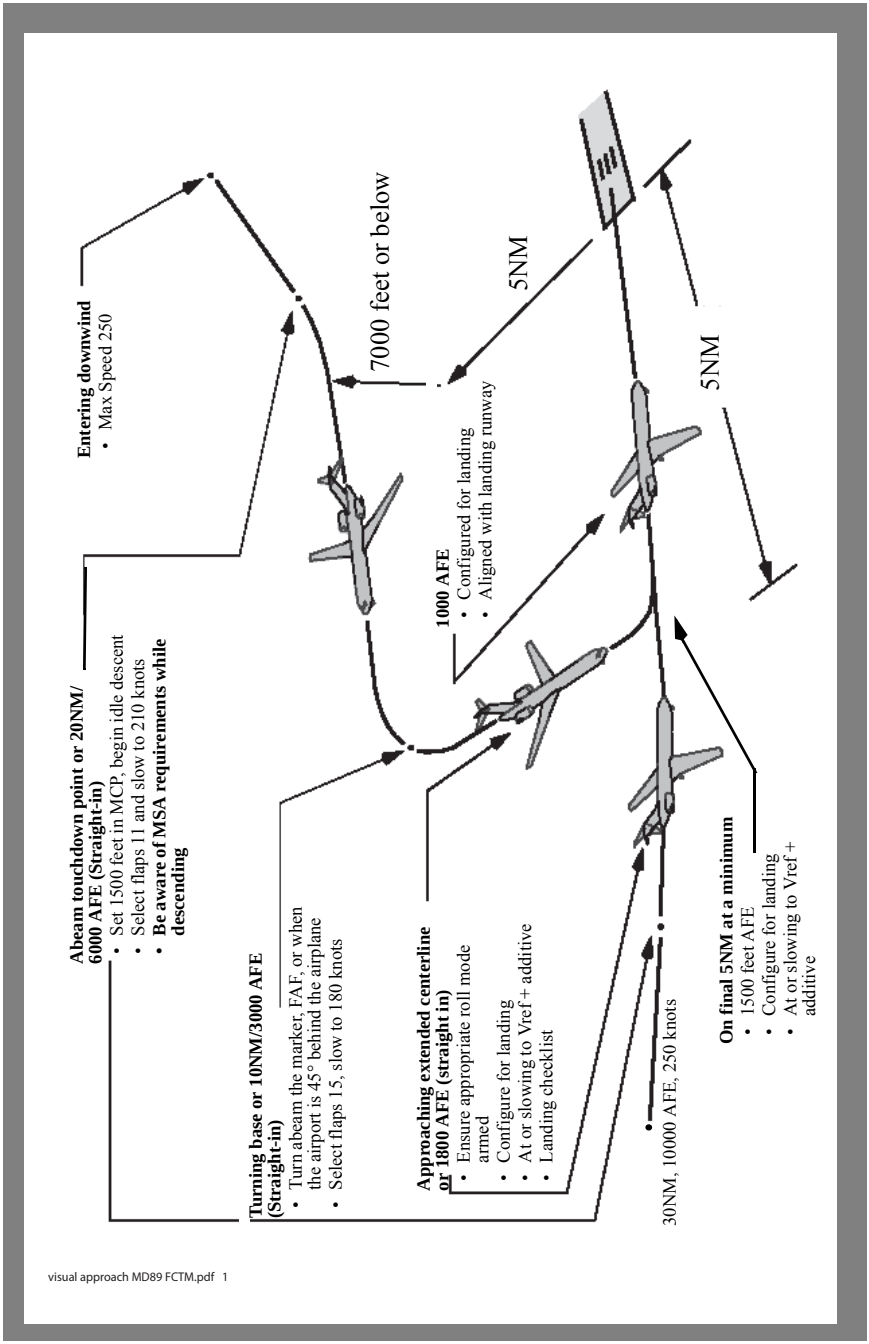
Visual Traffic Pattern Profile



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Engine Inoperative Approach Operations

This section describes pilot techniques associated with engine inoperative approaches. Techniques discussed minimize workload, improve crew coordination, and enhance flight safety. However, a thorough review of applicable non-normal checklists associated with engine inoperative flight is a prerequisite to understanding this section.

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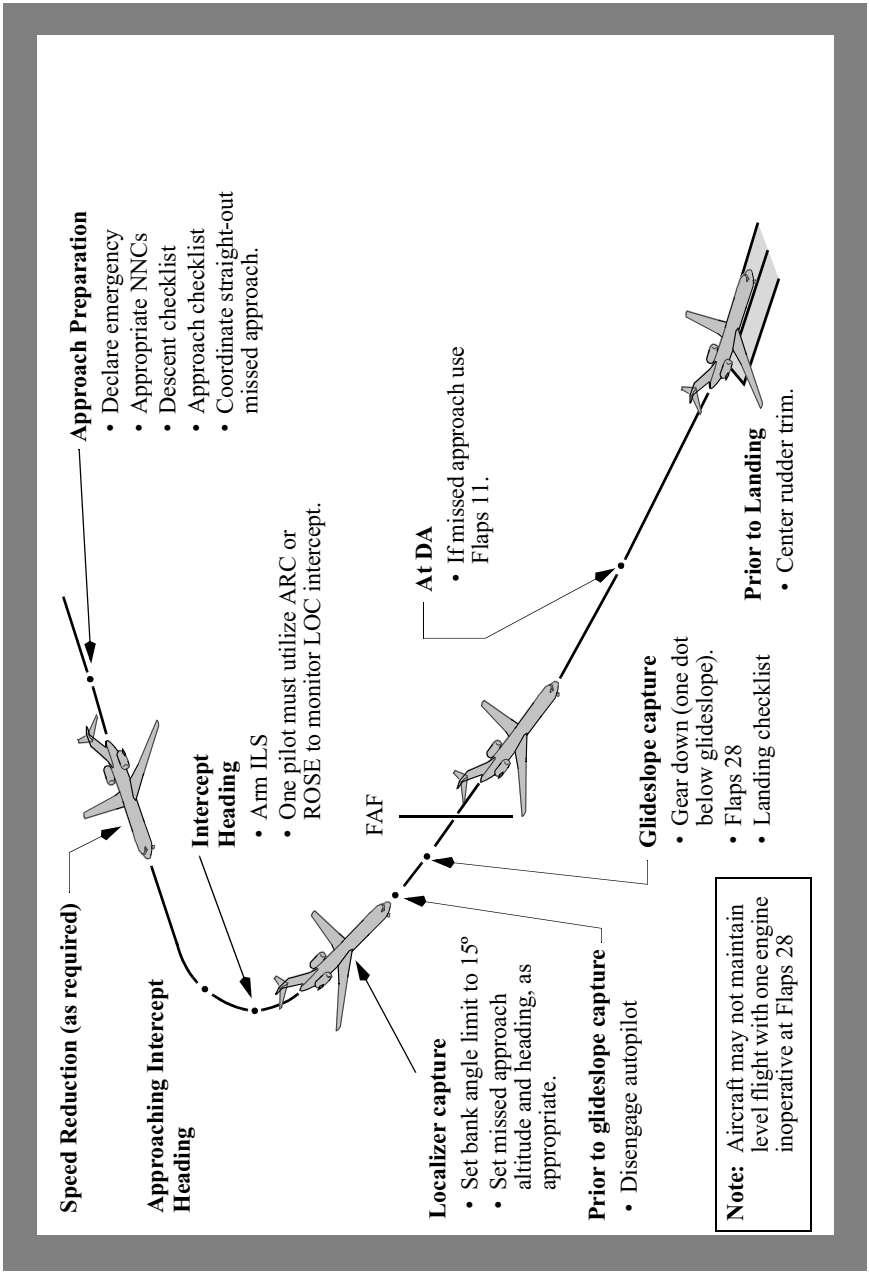
ILS Approach Profile - One Engine Inoperative



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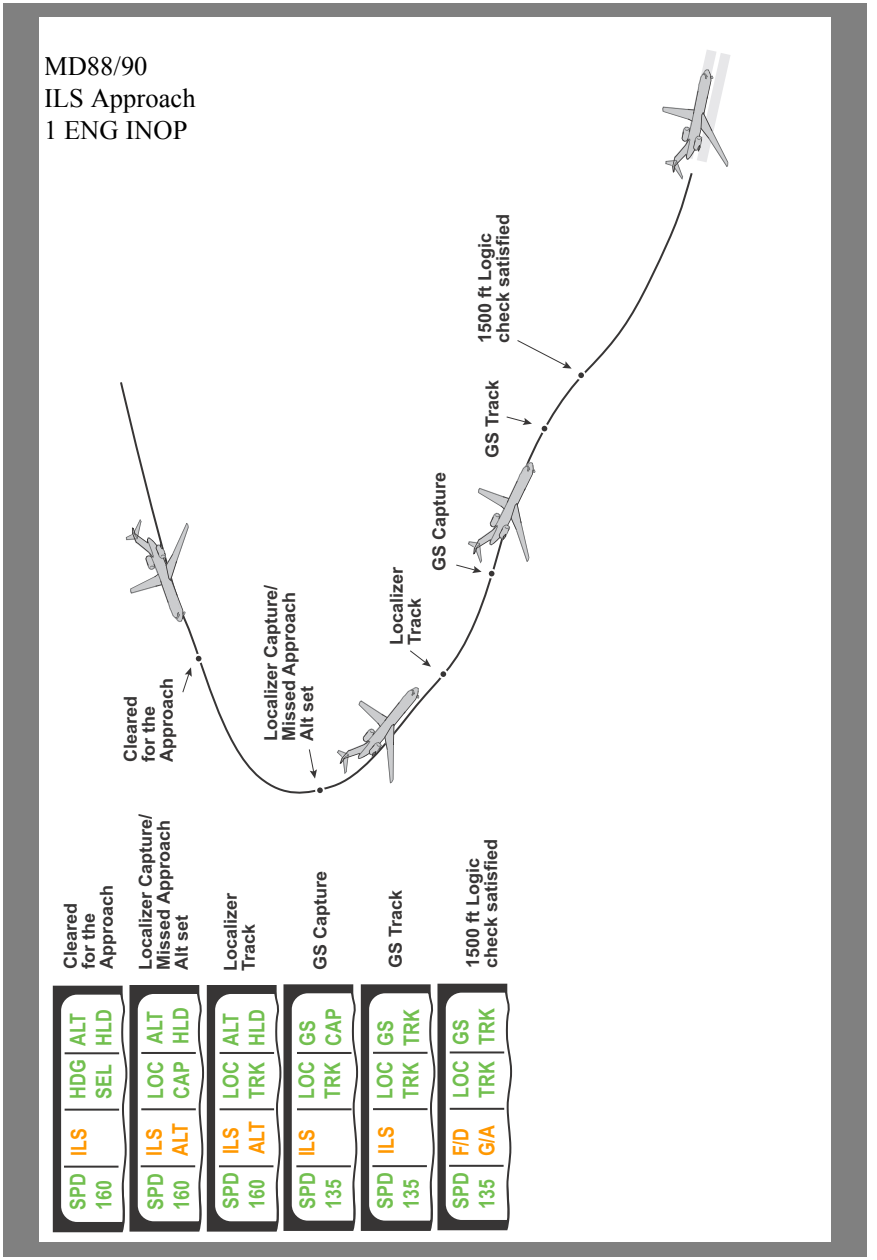
ILS Approach 1 ENG INOP FMA Progression



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ILS Approach - Engine Inoperative

Full rudder authority and rudder pedal steering capability are not affected by rudder trim. If touchdown occurs with the rudder still trimmed for the approach, be prepared for the higher rudder pedal forces required to track the centerline on rollout.

Engine Inoperative, Rudder Trim - All Instrument Approaches

During a coupled ILS approach below 1,500 feet AGL with LOC TRK, G/S TRK parallel rudder is engaged. This gives the autopilot rudder servo full rudder authority. The MD88/90 is not certified to conduct coupled Single Engine ILS approaches. With the autopilot on and parallel rudder engaged, single engine, rudder inputs may not be apparent from the actions of the control column. The parallel rudder may mask an out-of-trim condition. When the autopilot is disengaged for landing the sudden unexpected loss of rudder input combined with an out-of-trim condition, may cause an unstable approach.

With one engine inoperative, the rudder trim should be centered prior to landing. This allows most of the rudder pedal pressure to be removed when the thrust of the operating engine is retarded to idle at touchdown.

Full rudder authority and rudder pedal steering capability are not affected by rudder trim. If touchdown occurs with the rudder still trimmed for the approach, be prepared for the higher rudder pedal forces required to track the centerline on rollout.

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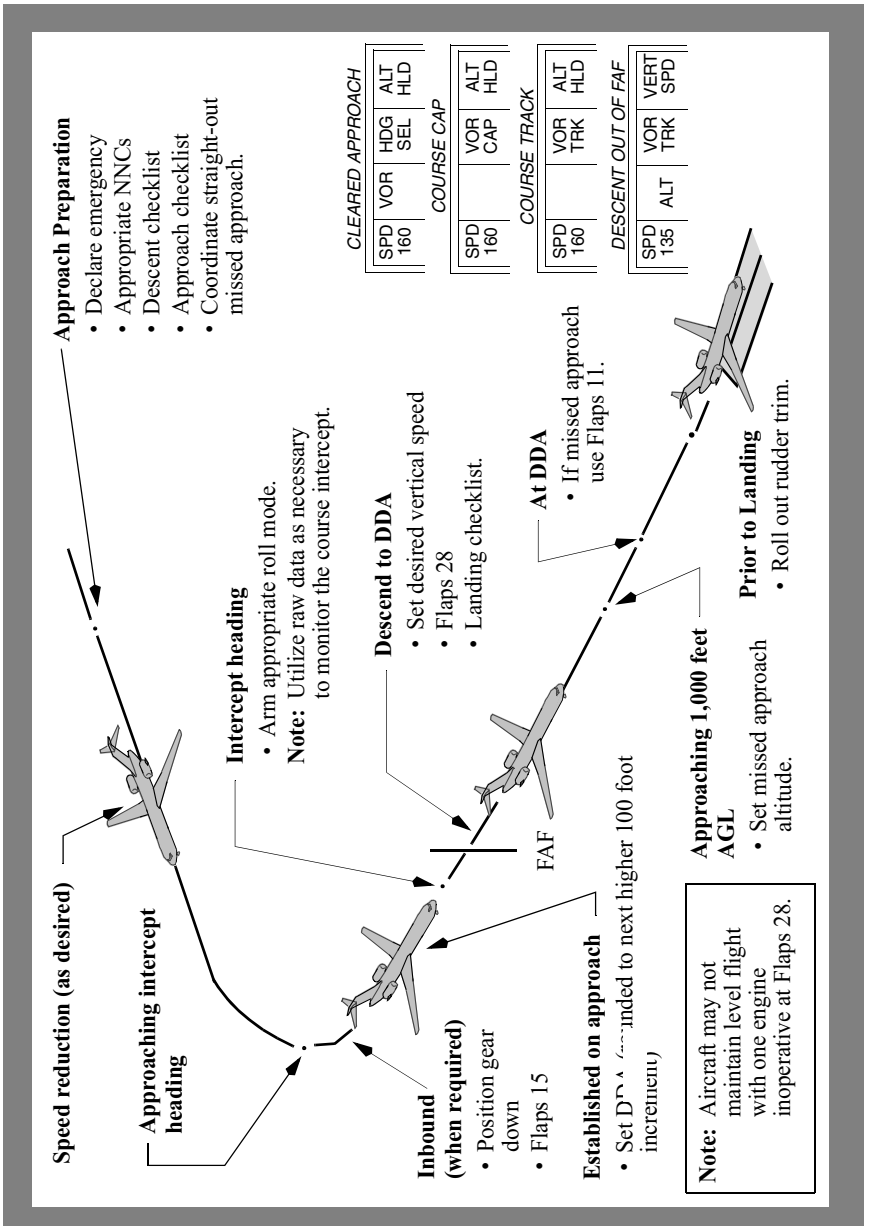
Non-ILS Instrument Approach Profile - One Engine Inoperative



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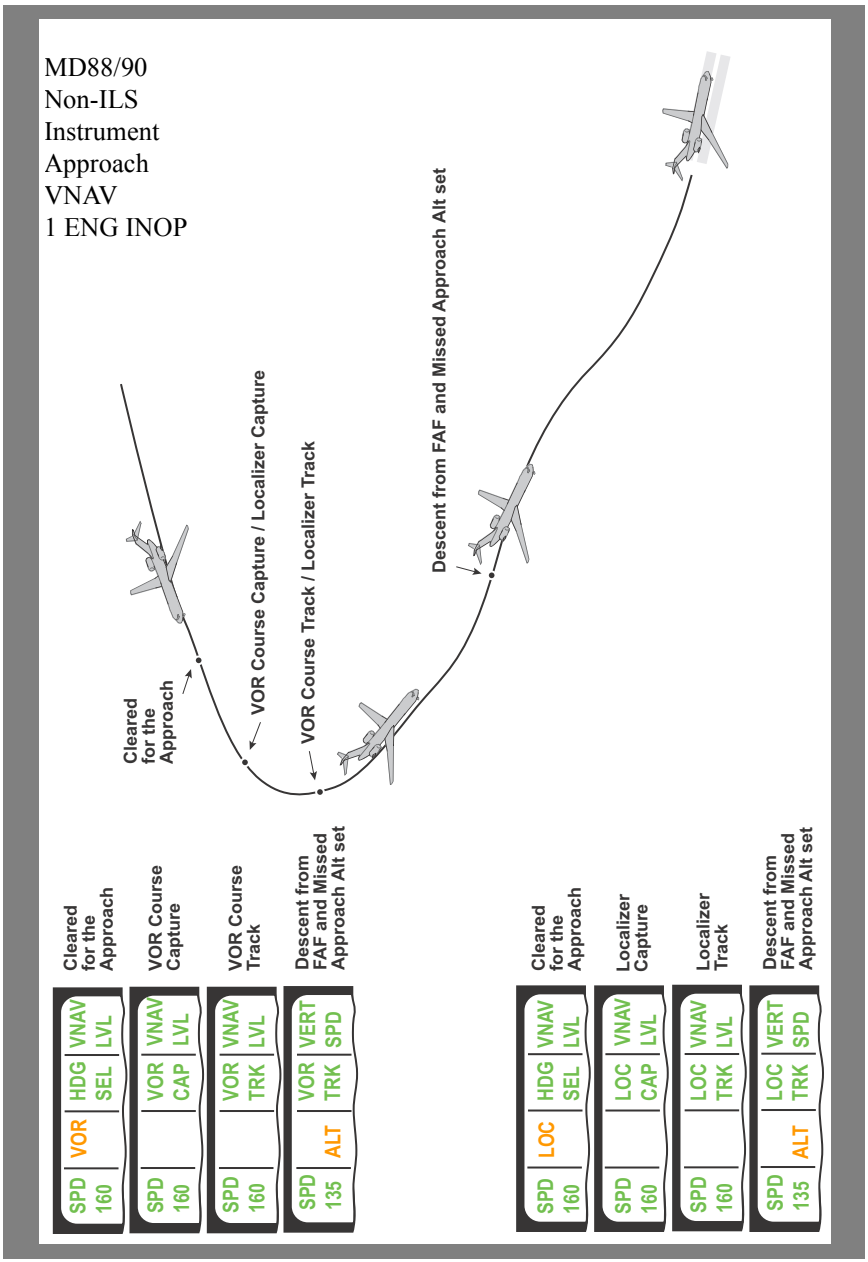
Non-ILS Instrument Approach VNAV 1 ENG INOP FMA Progression



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Maneuvering before and after the final approach fix with one engine inoperative is the same as for an all engine non-ILS approach However, delay selecting flaps 28 until starting final descent to avoid high power settings on the operating engine.

Autopilot is required for all non-ILS engine inoperative approaches.

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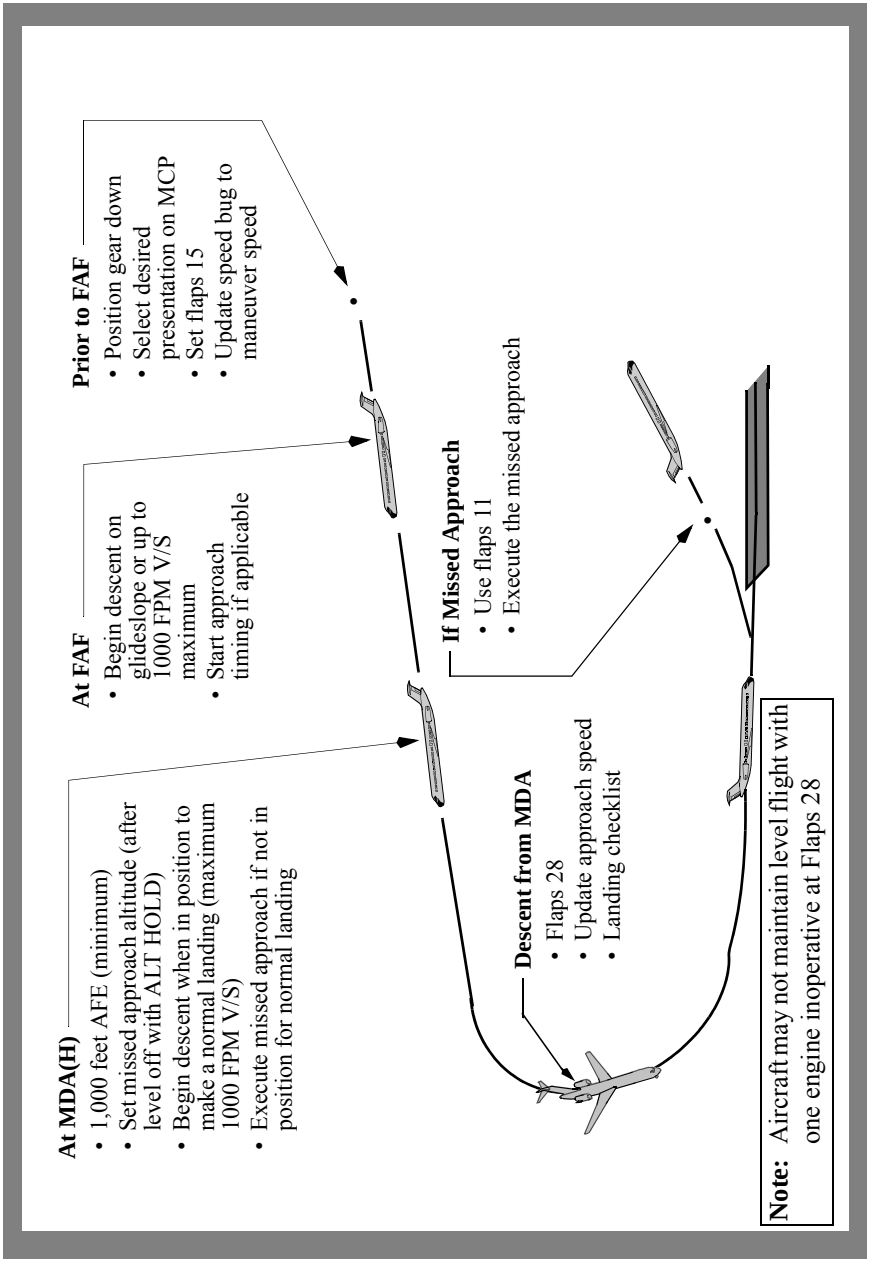
Circling Maneuver Profile - One Engine Inoperative



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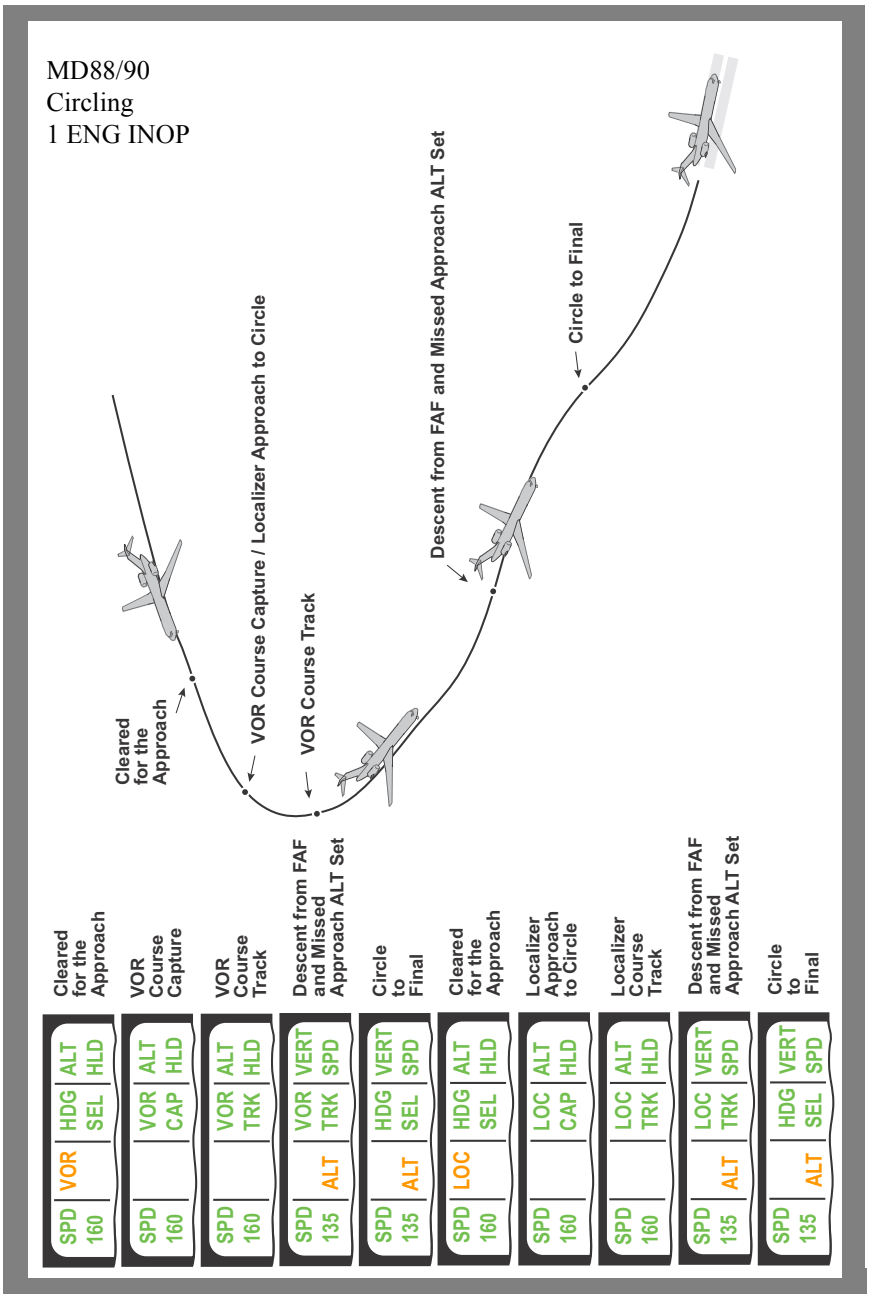
Circling 1 ENG INOP FMA Progression



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The captain must consider whether it is preferable to perform a circling approach or to divert to a more suitable airport. Fly approach at flaps 15 at appropriate maneuver airspeed. Select flaps 28 when starting descent from MDA and adjust speed. Coordinate a straight out missed approach or execute the appropriate single-engine procedure for the landing runway.

Engine Failure On Final Approach

If an engine failure should occur on final approach with flaps 40, the decision to continue the approach or execute a go-around should be made immediately. If the approach is continued, change the configuration from flaps 40 to flaps 28 and adjust speed accordingly.

If a go-around is required, follow the engine out go-around procedures.

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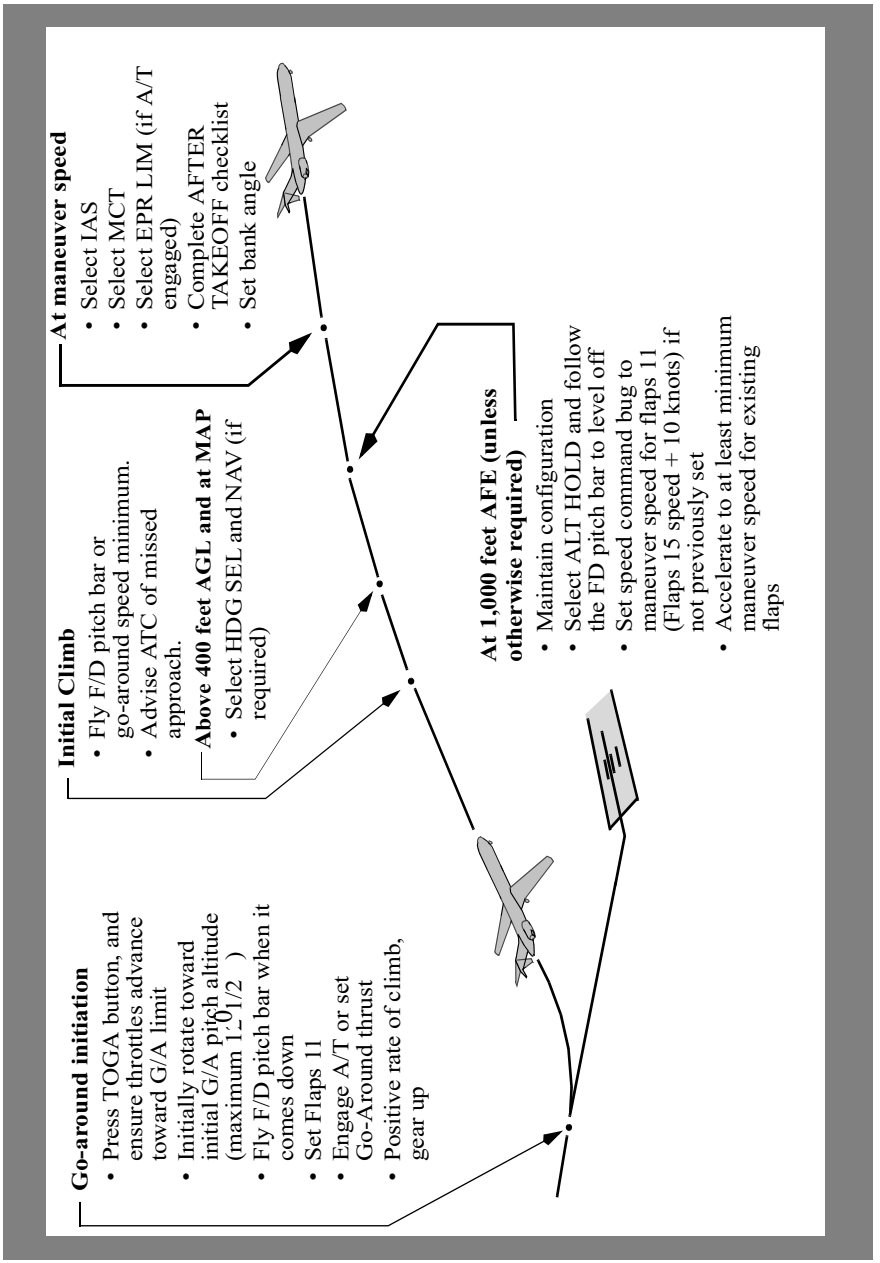
Go-Around and Missed Approach Profile - One Engine Inoperative



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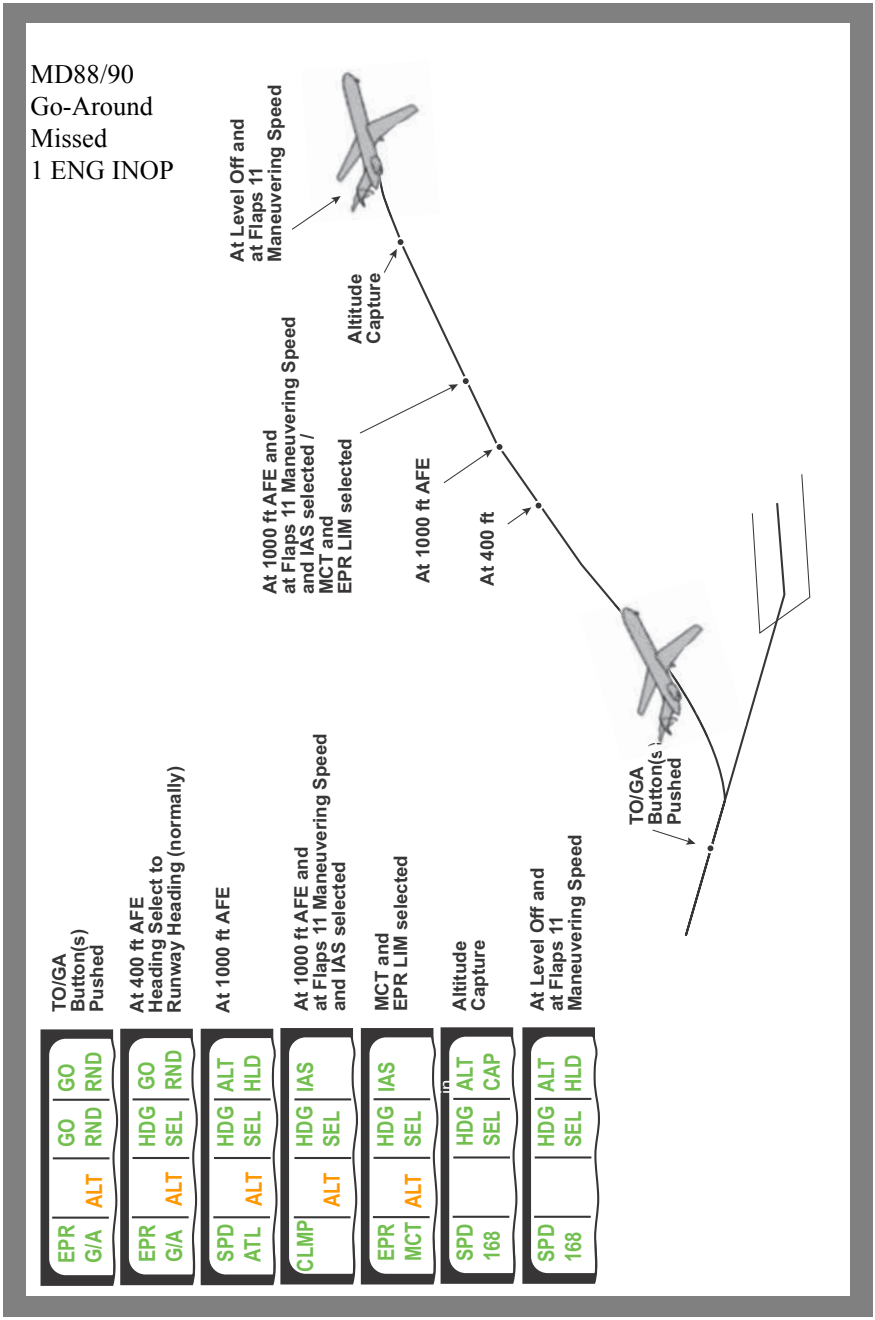
Go-Around Missed 1 ENG INOP FMA Progression



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Go-Around and Missed Approach - One Engine Inoperative

Pilot Flying	Pilot Monitoring
When a go-around is warranted:	
Advance throttles, push TO/GA button(s) and announce: • "TO/GA POWER", and either • "AUTOTHROTTLES ON" (if operable) or • "SET GO AROUND THRUST" (if A/Ts inop).	Select or verify AUTO THROT Switch on, - or - Adjust throttles to the EPR GA bugs. Verify FMA pitch and roll display GO RND, GO RND. Announce, "GO AROUND VERIFIED".
Verify: • Rotation to go-around pitch attitude, • Thrust setting is sufficient for the go-around, and • Proper FMA mode annunciation(s).	
Call "FLAPS 11".	Set flap lever as directed.
	Monitor airspeed and vertical speed. Verify a positive rate of climb and announce "POSITIVE RATE".
Confirm a positive rate of climb on the altimeter.	
Call "GEAR UP."	Position the landing gear handle to UP.
	Verify missed approach altitude is set.
Above 400 feet RA:	
Verify or call for the appropriate roll mode.	Select or verify roll mode.
At 1,000 feet AFE:	
Call "ALTITUDE HOLD, SET SPEED COMMAND BUG TO FLAPS 11 MANEUVERING SPEED"	Select ALT HLD and set the speed command bug.
At flaps 11 maneuvering speed:	
Call "IAS, MCT, EPR limit BANK ANGLE 25, AFTER TAKEOFF CHECKLIST."	Select IAS, MCT, EPR limit Set bank angle 25 and complete the After Takeoff Checklist
If another approach is warranted at the destination airport:	
Consider leaving flaps at 11 and maintain appropriate maneuvering speed.	Verify flaps 11 and appropriate maneuvering speed as directed.

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Pilot Flying	Pilot Monitoring
If a diversion is required:	
On course to the diversion airport: Select IAS and set speed, slat retract +20. Select EPR LIM. Set Speed Command bug to slat retract +20. Retract flaps and slats on schedule.	Verify IAS, Slat retract +20 set and Speed Command bug slat retract +20 set. Retract flaps and slats on schedule.
If using VNAV:	
Select CLB page ENG OUT and execute. Select VNAV. Retract flaps and slats on schedule. **Note:** Single engine climb speed (slat retract +20) is not a maneuvering speed.	Verify proper FMA annunciations. Retract flaps and slats on schedule.

The missed approach with an engine inoperative should be accomplished in the same manner as a normal missed approach, except use Flaps 11 for the go-around flap setting and accelerate to maneuvering speed at 1,000 feet AFE, or in accordance with single engine procedure in company pages. The pilot must control yaw with rudder and trim. Some rudder pedal pressure may be required even with full rudder trim.

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Engine Failure During Go-Around and Missed Approach

In the event of an engine failure during the missed approach, additional considerations are:

- If the approach was an ILS coupled or autoland approach, parallel rudder mode will be operative during go-around to assist in controlling yaw forces. Parallel rudder will remain until a mode change is initiated or go-around mode is canceled. PF should be prepared for manual rudder inputs should parallel rudder disengage unexpectedly.
- For non-coupled ILS approaches, PF must be prepared to make prompt rudder inputs as go-around power is applied to operating engine.
- VREF + 5 minimum climb speed should be maintained until missed approach altitude is reached. An engine-out missed approach climb to missed approach altitude may exceed 5-minute go-around thrust limit. Should the 5-minute limit be exceeded and MCT power is insufficient, expedite acceleration and clean up to resume climb to missed approach altitude.
- Transition to Go-Around and Missed Approach- One Engine Inoperative procedures.
- If approach climb limited, consider using 11/T.O. flap/slat setting.

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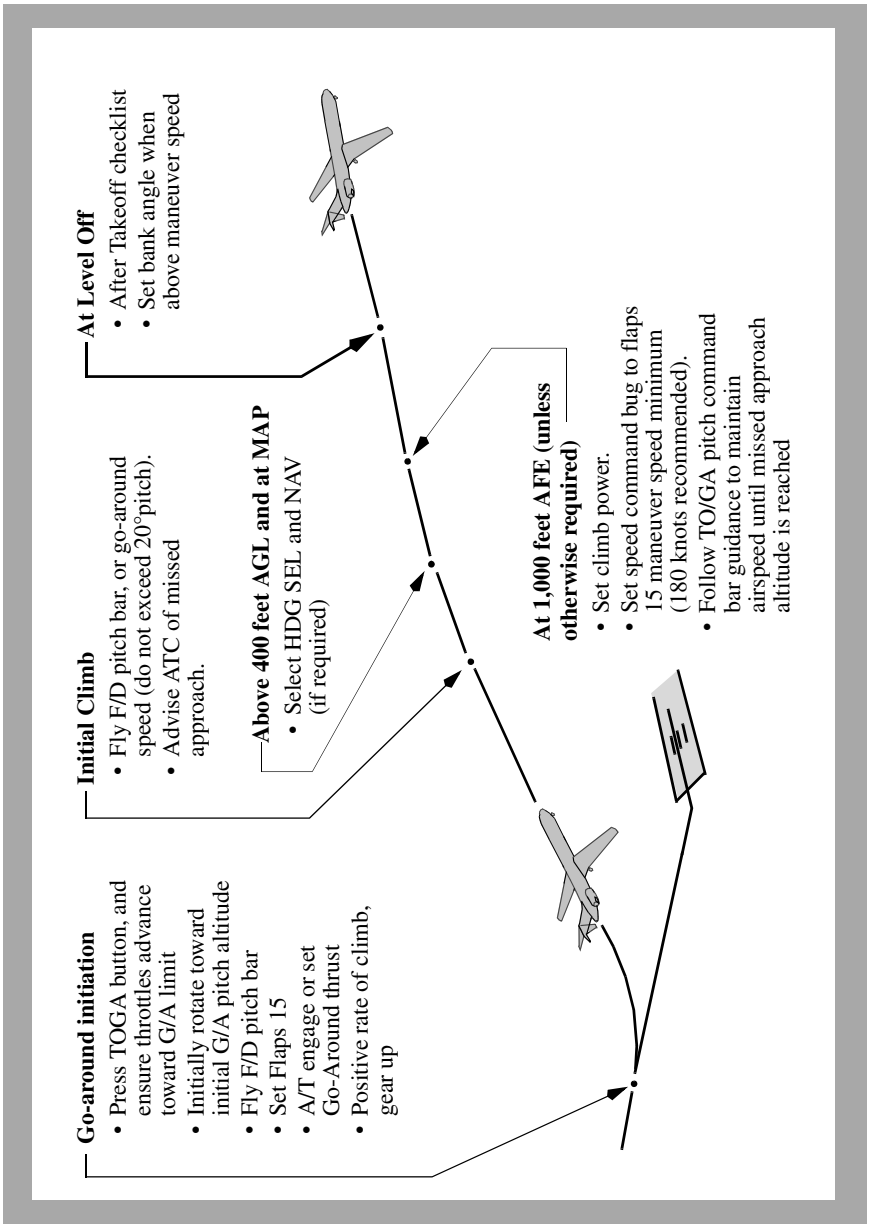
Go-Around and Missed Approach - All Approaches

Go-Around and Missed Approach Profile - All Approaches



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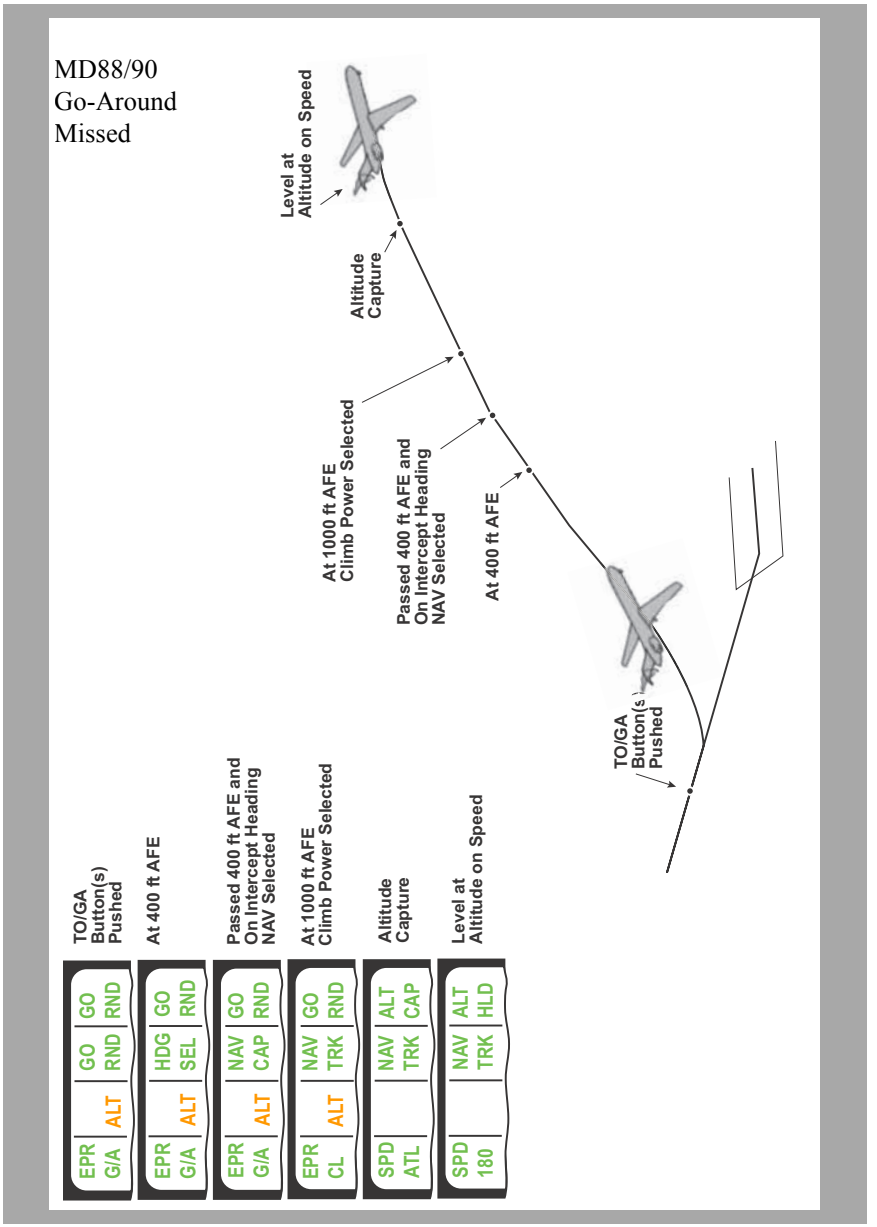
Go-Around Missed FMA Progression



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Go-Around and Missed Approach - All Engines Operating

The go-around and missed approach maneuver is generally performed in the same manner whether an instrument or visual approach was flown and defines pilot flying and pilot monitoring duties. The go-around and missed approach is flown using the Go-Around procedure described in the Vol. 1, NP.20, and utilizing Standard Callouts. The discussion in this section supplements those procedures.

If a go-around is required following an autopilot approach, leave the autopilot engaged. The pilot flying will verbalize “GO AROUND” push the TO/GA button(s) and verbalize “TO/GA power”. The pilot monitoring will verify that the FMA, pitch, roll, and autothrottle annunciations are GO RND, GO RND, EPR G/A. AP1 or AP2 should be illuminated. After FMA verification, the pilot monitoring will verbalize “GO AROUND VERIFIED” or call out any FMA omissions.

Note: The best practice to select TO/GA power is to use the heel of the hand to press both TO/GA buttons, while simultaneously pushing the throttles forward.

TO/GA Button(s) Pushed

If any FMA mode not annunciated during a go-around, or AP1 or AP2 not illuminated, any omission should be verbalized by the pilot monitoring.

Examples of FMA omissions are:

- GO RND is not annunciated - Callout - “GO AROUND NOT VERIFIED, PUSH THE TO/GA BUTTON(S)”
- AP1 or AP2 is not annunciated and the level of automation is flight director (FD) - Callout - “GO AROUND VERIFIED, AUTOPILOT IS OFF”
- LOC TRK and GS TRK are annunciated - Callout - “GO AROUND NOT VERIFIED, PUSH THE TO/GA BUTTON(S)”
- AT GA is not annunciated - Callout - “GO AROUND VERIFIED, NO AUTOTHROTTLES”

The pilot flying calls for flaps 15, ensures go-around thrust for the nominal climb rate is set, and monitors autopilot performance. Retract the landing gear after a positive rate of climb is indicated on the altimeter.

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Go-Around Maneuver - All Engines Operating

Pilot Flying	Pilot Monitoring
When a go-around is warranted:	
Advance throttles, push TO/GA button(s) and announce: • "TO/GA POWER", and either • "AUTOTHROTTLES ON" (if operable) or • "SET GO AROUND THRUST" (if A/Ts inop).	Select or verify AUTO THROT Switch on, - or - Adjust throttles to the EPR GA bugs. Verify FMA pitch and roll display GO RND, GO RND. Announce, "GO AROUND VERIFIED".
Verify: • Rotation to go-around pitch attitude, • Thrust setting is sufficient for the go-around, and • Proper FMA mode annunciation(s).	
Call "FLAPS 15".	Set flap lever as directed.
	Monitor airspeed and vertical speed. Verify a positive rate of climb and announce "POSITIVE RATE".
Confirm a positive rate of climb on the altimeter.	
Call "GEAR UP."	Position the landing gear handle to UP.
	Verify missed approach altitude is set.
Above 400 feet RA:	
Verify or call for the appropriate roll mode.	Select or verify roll mode.
At 1,000 feet AFE:	
Call "CLIMB POWER."	Select CL power on TRP and adjust throttles, if required.
Call "SPEED COMMAND BUG 180."	Set speed command bug to 180.
If another approach is warranted at the destination airport:	
Consider leaving flaps at 15 and maintain appropriate maneuvering speed.	Verify flaps 15 and appropriate maneuvering speed as directed.

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Pilot Flying	Pilot Monitoring
If a diversion is required:	
Select Speed Command 250 and call for IAS 250. Retract flaps and slats on schedule.	Verify Speed Command 250 and set IAS 250. Retract flaps and slats on schedule.
At level off altitude and above maneuvering speed:	
Call "AFTER TAKEOFF CHECKLIST."	Accomplish After Takeoff checklist.

Note: For missed approach priorities, refer to the Airway Manual, Ops Specs, General or the company pages, Critical Performance Procedures, Missed Approach/ Rejected Landing table.

If a go around is required following a manual instrument approach, or a visual approach, push the TO/GA button(s), call for flaps 15, ensure/set go-around thrust (if disconnected, connect the autothrottles), and rotate smoothly toward go-around attitude (maximum of 20° pitch). Then follow flight director commands and retract the landing gear after a positive rate of climb is indicated on the altimeter.

During an automatic go-around prior to touchdown, approximately 30 feet of altitude is lost. If touchdown occurs after a go-around is initiated, the go-around continues. Observe that the autothrottles apply go-around thrust or manually apply go-around thrust as the aircraft rotates to the go-around attitude.

Note: An automatic go-around cannot be initiated after touchdown.

The TO/GA pitch mode will command pitch to maintain a safe margin above stall speed. If the flight director pitch bars are not available, fly a minimum of speed book go-around. Do not exceed 20° nose up.

Autothrottles command EPR LIM for go-around. If not previously accomplished, set the missed approach altitude and bank angle limiter to 15°. Above 400 feet AGL and at the missed approach point select HDG SEL and NAV, if required.

The best practice is to call for "HEADING SELECT" at the turn point, and verify bank angle limiter to 15°. When on an intercept to the missed approach course, select NAV. The aircraft must be above 400 feet, and the PF's ND must be in the MAP mode prior to selection of NAV.

Note: The roll mode on the FMA must be out of GA in order to arm NAV (i.e., HDG SEL).

Note: The pilot may initiate a go around at any point when flying an instrument approach. However, do not make any turns until reaching the missed approach point.

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The minimum altitude for flap retraction during a normal takeoff is not normally applicable to a go around procedure. However, obstacles in the missed approach flight path must be taken into consideration. Climb at GA speed at flaps 15 until reaching the missed approach altitude.

If initial maneuvering is required during the missed approach, do the missed approach procedure through gear up before initiating the turn. Delay further flap retraction until initial maneuvering is complete and a safe altitude and appropriate speed are attained. If departing the area, continue climb out as in a normal takeoff. Delay use of VNAV until appropriate FMS entries are complete. Complete the AFTER TAKEOFF checklist and accelerate to 250 knots.

Note: FMS altitude constraints are not honored during the go-around phase. For example, if there is an altitude restriction associated with a missed approach waypoint, the aircraft will climb to the MCP altitude and ignore the altitude constraint in the MCDU. Instead, the MCP must be set to the constraint altitude until passing the waypoint. Conditional waypoints (e.g., "at 2800 turn left direct ABC") are honored during the go-around phase.

Note: When rejecting a landing past the published missed approach point, pilots must be aware of any published special departure procedure for terrain clearance. Refer to the Airway Manual, Ops Specs, General, and the company pages.

Go-Around Not Requiring a Climb (Approach Cancellation Prior to Descent)

Should an approach clearance be canceled prior to descent, make appropriate MCP inputs and fly the aircraft to comply with either ATC or specific instrument approach procedure instructions. Disarm any armed modes and use the appropriate roll and pitch modes (HDG SEL, ALT HLD) to maneuver as required. Accelerate and retract landing gear and flaps on schedule.

Go-Around from an Altitude Above the Acceleration Height

Executing a go-around above the normal acceleration height (typically 1,000 feet AFE) is often confusing. It is important that both pilots not focus entirely on the MCP. The PF should continue to "fly the aircraft" while the PM assists as directed by the PF. Selecting TOGA provides immediate flight guidance.To execute a short climb use VERT SPD to produce a 1,000 fpm climb, set Speed command bug to 180 KIAS, retract the flaps to 15, then retract the landing gear. Use HDG SEL/NAV as appropriate. Alternatively, if the Autoland approach mode (LND) has been selected and LOC TRK/GS TRK are displayed on the FMA, pitch and roll modes other than TOGA cannot be selected unless the autopilot and flight directors are turned OFF and back ON or the ILS frequency is detuned. The FMA will annunciate HDG HLD and V/S. This can be done, however it requires a greater degree of coordination between the PF and PM.

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Go-Around from an Altitude Below the Acceleration Height

Should a go-around be initiated below the acceleration height, use normal go-around procedures.

Low Altitude Level Off - Low Gross Weight

When accomplishing a low altitude level off following a go-around at a low gross weight, the crew should consider the following factors:

- Altitude capture can occur just after the go-around is initiated due to the proximity of the level off altitude and the high climb rate of the aircraft.
- There may not be enough altitude below the intended level-off altitude to complete the normal capture profile and an overshoot may occur unless crew action is taken.

To prevent an altitude and/or airspeed overshoot, the crew should consider doing one or more of the following:

- Use the autothrottle.
- Reduce to climb thrust earlier than normal.
- Disengage the autopilot and complete the level off manually if there is a possibility of an overshoot.
- If the autothrottle is not available, be prepared to use manual thrust control as needed to manage speed and prevent flap overspeed.

Go-Around after Touchdown

WARNING: After reverse thrust is initiated, a full stop must be made.

If a go-around is initiated before touchdown and touchdown occurs, continue with normal go-around procedures. The F/D go-around mode will continue to provide go-around guidance commands throughout the maneuver.

If a go-around is initiated after touchdown but before thrust reverser selection, auto spoilers retract and autobrakes disarm as throttles are advanced. The AUT G/A mode is disarmed, and F/D G/A mode is armed and available for 20 seconds.

If an engine stays in reverse, safe flight is not possible.

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Landing
Table of Contents

Chapter 6
Section TOC

Visual Approach Slope Indicator (VASI / T-VASI) 6.1
Three Bar VASI / T-VASI 6.1
VASI Landing Geometry 6.2

Precision Approach Path Indicator 6.3
PAPI Landing Geometry 6.3

Landing Geometry 6.4
Visual Aim Point 6.4
Runway Markings (Typical) 6.5
Threshold Height 6.6

Tail Strike 6.6
Landing Risk Factors 6.6

Flare and Touchdown 6.8
Airspeed Control 6.10
Landing Flare Profile 6.10
Pitch and Roll Limit Conditions 6.11
Bounced Landing Recovery 6.12
Rejected Landing 6.12

Landing Roll 6.12
Spoilers 6.13
Directional Control and Braking during Landing Roll 6.14
Factors Affecting Landing Distance 6.14
Wheel Brakes 6.17
Reverse Thrust Operation 6.22

Crosswind Landings 6.26
Crosswind Landing Guidelines 6.26

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Crosswind Landing Techniques. 6.26

Overweight Landing 6.27

Overweight - General. 6.27

Overweight Autolands 6.28

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Visual Approach Slope Indicator (VASI / T-VASI)

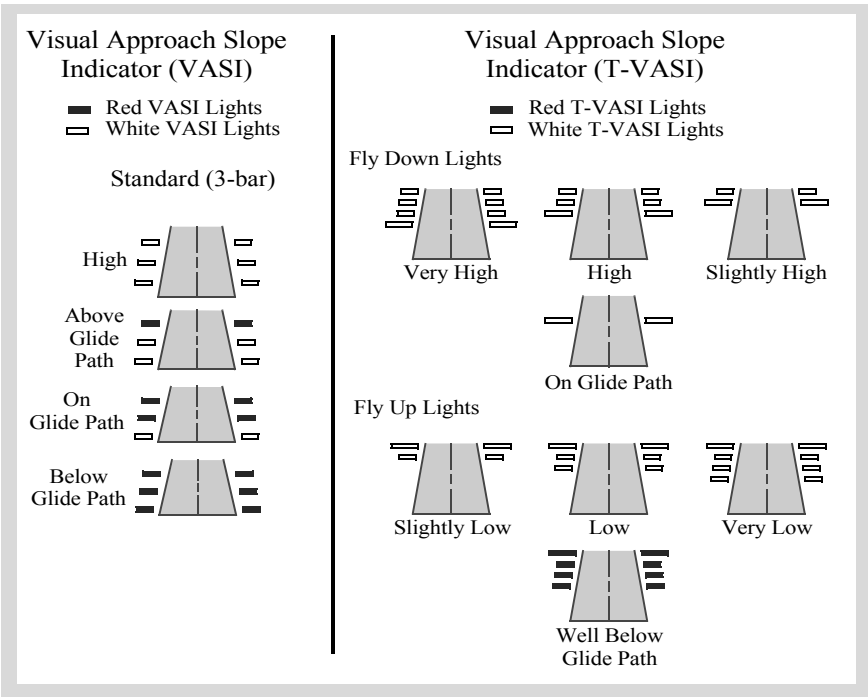
The VASI is a system of lights arranged to provide visual descent guidance information during the approach. All VASI systems are visual projections of the approach path normally aligned to intersect the runway at a point 1,000 or 1,800 feet beyond the threshold. Flying the VASI glide slope to touchdown is the same as selecting a visual aim point on the runway adjacent to the VASI installation.

When using a two-bar VASI, the difference between the eye reference path and the gear path results in a normal approach and threshold height. It provides useful information in alerting the crew to low profile situations.

Some airports have three-bar VASI which provides two visual glide paths. The additional light bar is located upwind from a standard two-bar installation. When the aircraft is on the glide path, the pilot sees the two red bars over one white bar. Three-bar VASI may be safely used with respect to threshold height, but may result in landing further down the runway.

For a T-VASI, flying the approach with one additional white fly down light visible provides additional wheel clearance.

Three Bar VASI / T-VASI



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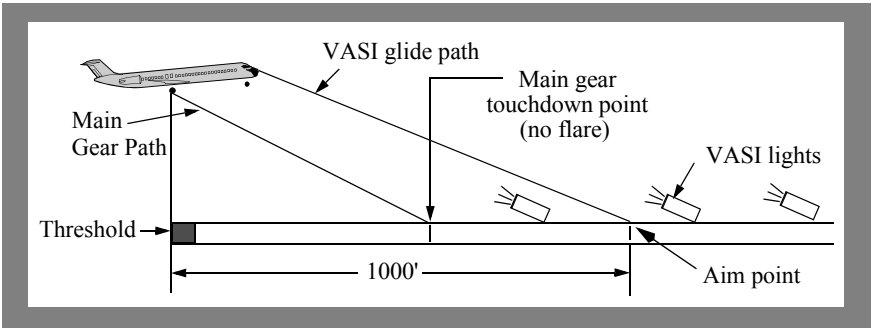
VASI Landing Geometry

Two-bar VASI installations provide one visual glide path which is normally set at 3°. Three-bar VASI installations provide two visual glide paths. The lower glide path is provided by the near and middle bars and is normally set at 3° while the upper glide path, provided by the middle and far bars, is normally 1/4° higher (3.25°). This higher glide path is intended for use only by high flight deck (long wheelbase) aircraft to provide a sufficient threshold crossing height.

Two Bar/Three Bar VASI Landing Geometry

The following diagrams use these conditions:

- Data is based upon typical landing weight
- Aircraft body attitudes are based on Flaps 28 + 5 and should be reduced by 1° for each 5 knots above this speed
- Pilot eye height is measured when the main gear is over the threshold.



Flaps 28			AIM Point at 1,000 Feet		
Airplane Model	Visual Glide Path (degrees)	Airplane Body Attitude (degrees)	Threshold Height		Main Gear Touchdown Point - no flare (feet)
			Pilot Eye Height (feet)	Main Gear Height (feet)	
MD-88	3.0	5.5	52	28	526
MD-90	3.0	4.9	52	32	606

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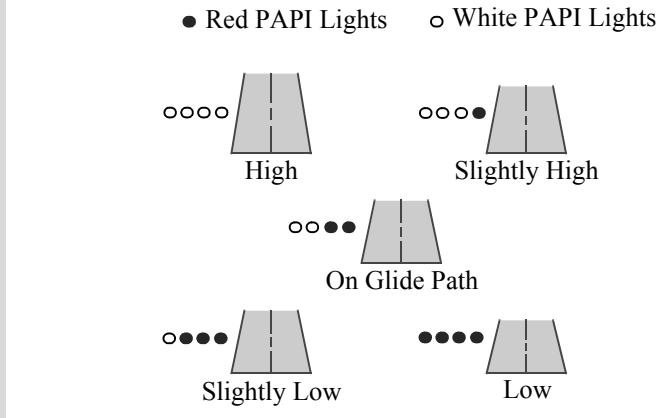
Precision Approach Path Indicator

The Precision Approach Path Indicator (PAPI) uses lights which are normally on the left side of the runway. They are similar to the VASI, but are installed in a single row of light units.

When the aircraft is on a normal 3° glide path, the pilot sees two white lights on the left and two red lights on the right. The PAPI may be safely used with respect to threshold height, but may result in landing further down the runway. The PAPI is normally aligned to intersect the runway 1,000 to 1,500 feet beyond the threshold.

PAPI Landing Geometry



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Landing Geometry

Visual Aim Point

CAUTION: To avoid a touchdown short of the threshold, avoid approaches on a shallow visual glidepath (less than 2.5°) and using runway aiming points less than the 1,000 feet mark.

During visual approaches many techniques and methods are used to ensure main landing gear touchdown at the desired point on the runway. One of the most common methods used is to aim at the desired gear touchdown point on the runway, then adjust the final approach glide path until the selected point appears stationary in relation to the aircraft (the point does not move up or down in the pilot's field of view during the approach).

This method is acceptable in smaller aircraft because of the small difference between landing gear path and eye level path. Flare distance accounts for the small difference in paths. Gear touchdown occurs very near the visual aim point. However, in larger airplanes, the difference in gear path and eye-level path has increased because of the longer wheelbase and the increased flight deck height. Consequently, the main gear do not touch down on the runway at the selected visual aim point.

The gear touchdown point versus the visual aim point varies with the angle of the approach. For example on a low angle or flat approach, the gear will touch down much closer to the approach end of the runway given the same visual aim point on the runway. This difference between gear path and eye level path must be accounted for by the pilot.

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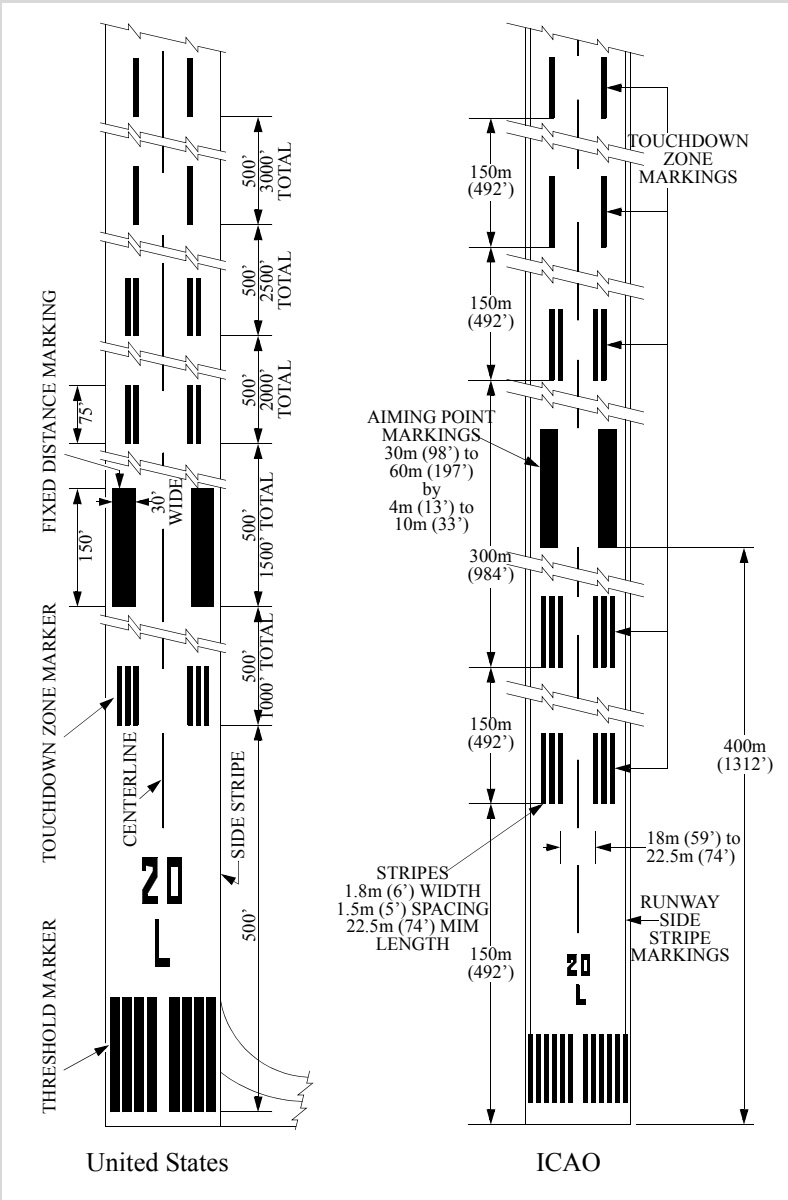
Runway Markings (Typical)

The following runway markings are for runways served by a precision approach.



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Threshold Height

Threshold height is a function of glide path angle and landing gear touchdown target. Threshold height for main gear and pilot eye level is shown in the Two Bar/Three Bar VASI Landing Geometry tables in this chapter. Special attention must be given to establishing a final approach that assures safe threshold clearance and gear touchdown at least 1,000 feet down the runway. If automatic callouts are not available, the radio altimeter should be used to assist the pilot in judging terrain clearance, threshold height, and flare initiation height.

Tail Strike

Tail strike occurs when the lower aft fuselage or tail skid (as installed) contacts the runway during takeoff or landing. A significant factor that appears to be common is the lack of flight crew experience in the model being flown. Understanding the factors that contribute to a tail strike can reduce the possibility of a tail strike occurrence.

Landing Risk Factors

A tail strike on landing tends to cause more serious damage than the same event during takeoff and is usually more expensive and time consuming to repair. In the worst case, the tail can strike the runway before the landing gear, thus absorbing large amounts of energy for which it is not designed. The aft pressure bulkhead is often damaged as a result.

Any one of the following landing risk factors may precede a tail strike:

Unstabilized Approach

An unstabilized approach is the biggest single cause of tail strike. At any altitude, if the stabilized approach criteria cannot be established and maintained, initiate a go-around.

Flight recorder data show that flight crews who continue with an unstabilized condition below 500 feet seldom stabilize the approach. When the airplane arrives in the flare, it often has either excessive or insufficient airspeed. The result is a tendency toward large thrust and pitch corrections in the flare, often culminating in a vigorous pitch change at touchdown resulting in tail strike shortly thereafter. If the pitch is increased rapidly when touchdown occurs as ground spoilers deploy, the spoilers add additional nose up pitch force, reducing pitch authority, which increases the possibility of tail strike. If the airplane is slow, increasing the pitch attitude in the flare does not effectively reduce the sink rate, and in some cases may increase it.

A firm touchdown on the main gear is often preferable to a soft touchdown with the nose rising rapidly.

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Holding Off in the Flare

The second most common cause of a landing tail strike is an extended flare, with a loss in airspeed that results in a rapid loss of altitude, (a dropped-in touchdown). This can also be caused by flaring high. This condition is often precipitated by a desire to achieve an extremely smooth/soft landing. A very smooth/soft touchdown is not essential, nor even desired, particularly if the runway is wet. During the flare, the pilot should not concentrate on airspeed, but on aircraft attitude using external cues.

Trimming in the Flare

Trimming the stabilizer in the flare may contribute to a tail strike. The pilot flying may easily lose the feel of the elevator while the trim is running. Too much trim can raise the nose, even when this reaction is not desired. The pitch up can cause a balloon, followed either by dropping in or pitching over and landing in a three-point attitude. Flight crews should trim the airplane during the approach, but not in the flare.

Mishandling of Crosswinds

When the airplane is placed in a sideslip attitude to compensate for the wind effects, this cross-control maneuver reduces lift, increases drag, and may increase the rate of descent. If the airplane then descends into a turbulent surface layer, particularly if the wind is shifting toward the tail, the stage is set for tail strike.

The combined effects of high closure rate, shifting winds with the potential for a quartering tail wind, can result in a sudden drop in wind velocity commonly found below 100 feet. Combining this with turbulence can make the timing of the flare very difficult. The pilot flying can best handle the situation by using additional thrust, if needed, and by using an appropriate pitch change to keep the descent rate stable until initiation of the flare. Flight crews should clearly understand the criteria for initiating a go-around and plan to use this avoidance maneuver when needed.

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Over-Rotation during Go-Around

Go-arounds initiated very late in the approach, such as during the landing flare or after touching down, are a common cause of tail strikes. When the go-around mode is initiated, the flight director immediately commands a go-around pitch attitude. If the pilot flying abruptly rotates up to the pitch command bar, a tail strike can occur before the airplane responds and begins climbing. During a go-around, an increase in thrust as well as a positive pitch attitude is needed. If the thrust increase is not adequate for the increased pitch attitude, the resulting speed decay will likely result in a tail strike. Another contributing factor in tail strikes may be a strong desire by the flight crew to avoid landing gear contact after initiating a late go-around when the airplane is still over the runway. In general, this concern is not warranted because a brief landing gear touchdown during a late go-around is acceptable. This had been demonstrated during autoland and go-around certification programs.

Flare and Touchdown

The techniques discussed here are applicable to all landings including one engine inoperative landings, crosswind landings, and landings on slippery runways. Unless an unexpected or sudden event occurs, such as windshear or collision avoidance situation, it is not appropriate to use sudden, violent, or abrupt control inputs during landing. Begin with a stabilized approach on speed, in trim and on glide path.

Note: When a manual landing is planned from an approach with the autopilot connected, the transition to manual flight should be planned early enough to allow the pilot time to establish aircraft control before beginning the flare. The PF should consider disengaging the autopilot and disconnecting the autothrottle 1 to 2 nm before the threshold, or approximately 300 to 600 feet above field elevation.

When the threshold passes under the aircraft nose and out of sight, shift the visual sighting point to the far end of the runway. Shifting the visual sighting point assists in controlling the pitch attitude during the flare. Maintaining a constant airspeed and descent rate assists in determining the flare point. Initiate the flare when the main gear is approximately 20 feet above the runway by increasing pitch attitude approximately 2° - 3°. This slows the rate of descent. Maintain the same attitude with slight increased back pressure to touchdown. Ground effect is equal to approximately 200-300 fpm decrease in rate of descent. Elevators are sensitive - harsh inputs may result in ballooning.

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After the flare is initiated, smoothly retard the throttles to idle, and make small pitch attitude adjustments to maintain the desired descent rate to the runway. Ideally, main gear touchdown should occur simultaneously with throttles reaching idle. Hold sufficient back pressure on the control column to keep the pitch attitude constant. A touchdown attitude as depicted in the Landing Flare Profile Chart below is normal with an airspeed of approximately VREF plus any gust correction.

Avoid rapid control column movements during the flare. If the flare is too abrupt and thrust is excessive near touchdown, the aircraft tends to float in ground effect. Do not allow the aircraft to float or attempt to hold it off. Fly the aircraft onto the runway at the desired touchdown point and at the desired airspeed.

Note: Do not trim during the flare or after touchdown. Trimming in the flare increases the possibility of a tail strike.

Prolonged flare increases aircraft pitch attitude 2° to 3°. When prolonged flare is coupled with a misjudged height above the runway, a tail strike is possible. Do not prolong the flare in an attempt to achieve a perfectly smooth touchdown. A smooth touchdown is not the criterion for a safe landing.

Typically, the pitch attitude increases slightly during the actual landing, but avoid over-rotating. Do not increase the pitch attitude, trim, or hold the nose wheel off the runway after landing. This could lead to a tail strike.

Note: Do not aerobrake.

Note: Large nose up stabilizer trim settings (10°-12°) during landing reduces elevator authority during flare. In this circumstance, delay reducing power to idle until arresting the descent in the flare.

CAUTION: The tail skid will touch the runway at a body angle of approximately 10.5° nose up. The thrust reversers will contact at approximately 8° nose up.

Desired speed:

- Before flare: VREF +5 or wind additive
- Flare initiation: VREF to VREF + 5
- After flare: VREF to VREF -5

Ten knots above computed approach speed will increase the minimum landing distance approximately 20%.

If a greater than desired sink rate develops during the flare, or if the pitch inputs are not flaring the aircraft as desired, the MD-88/90 generally requires a power addition rather than more pitch up input to decrease the sink rate. Promptly fly the nose to the runway.

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Airspeed Control

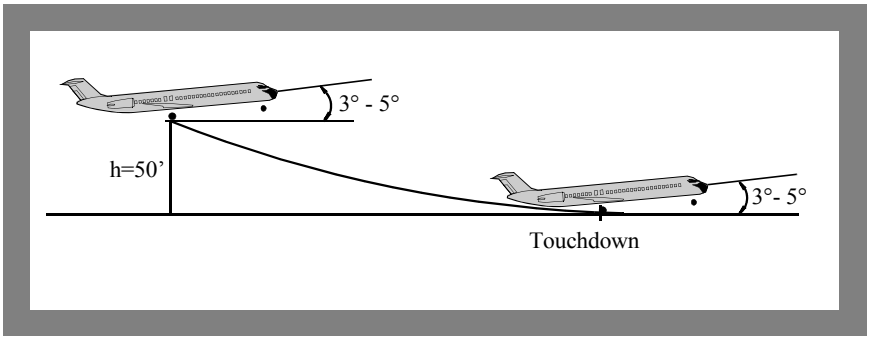
Use the FAST/SLOW indicator as the primary speed reference during approach and landing. At lighter weights, the autothrottles may cause your speed to increase due to the inability of the autothrottle system to retard the power past the LOW LIM setting.

If the autothrottle is or will be disconnected prior to landing, maintain VREF plus the wind additive until approaching the flare. The steady headwind additive is bled off before touchdown while the gust correction is maintained to touchdown. Plan to touchdown at VREF plus the gust correction. With proper airspeed control and thrust management, touchdown should occur at no less than VREF - 5 knots.

Landing Flare Profile

The following diagram uses these conditions:

- 3° approach glide path
- Flare distance is approximately 1,000 to 2,000 feet beyond the threshold
- Typical landing flare times range from 4 to 8 seconds and are a function of approach speed
- Aircraft body attitudes are based upon typical landing weights, flaps 28, VREF 28 + 5 knots (approach) and VREF 28 + 0 (touchdown).



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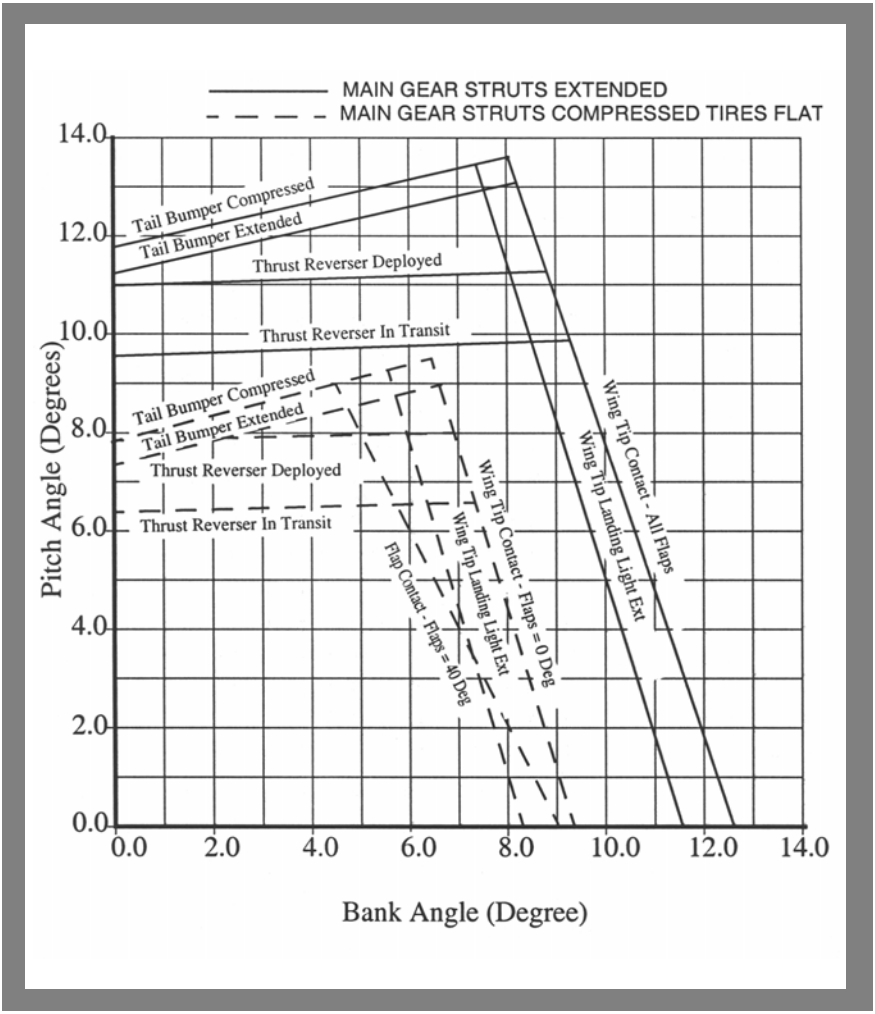
Pitch and Roll Limit Conditions

Bank Angle Limitations for Various Pitch Attitudes - Landing figure illustrates body roll angle/pitch angles at which the airplane structure contacts the runway. Prolonged flare increases the body pitch attitude 2° to 3°. When prolonged flare is coupled with a misjudged height above the runway aft body contact is possible.

Fly the airplane onto the runway at the desired touchdown point and at the desired airspeed. Do not hold it off and risk the possibility of a tailstrike.

Note: A smooth touchdown is not the criterion for a safe landing.



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Bounced Landing Recovery

CAUTION: Tail strikes or nosewheel structural damage can occur if large forward or aft control column movements are made prior to touchdown.

If the aircraft should bounce, hold or re-establish a normal landing attitude and add thrust as necessary to control the rate of descent. Thrust need not be added for a shallow bounce or skip. When a high, hard bounce occurs, initiate a go-around. Apply go-around thrust and use normal go-around procedures. Do not retract the landing gear until a positive rate of climb is established because a second touchdown may occur during the go-around.

If higher than idle thrust is maintained through initial touchdown, the automatic spoiler deployment may be disabled even when the speedbrakes are armed.

The spoilers may disarm and not automatically deploy on the subsequent (2nd) touchdown.

Rejected Landing

A rejected landing is defined as a go-around initiated after the MAP or below MDA/DA. Refer to chapter 5, Go-Around and Missed Approach and Go-Around after Touchdown, for more information on this subject.

Landing Roll

CAUTION: Pitch rates sufficient to cause airplane structural damage can occur if large nose down control column movement is made prior to nose wheel touchdown.

CAUTION: (88) Lower thrust reverser buckets may contact runway if pitch attitude is in excess of 8°.

Avoid touching down with thrust above idle since this may prevent proper spoiler actuation and increases landing roll.

After main gear touchdown, initiate the landing roll procedure. If the ground spoilers do not extend automatically move the spoiler handle to the AFT and latched position (up) without delay.

Fly the nose wheel smoothly onto the runway without delay by relaxing aft control column pressure. Control column movement forward of neutral should not be required. Do not attempt to hold the nose wheel off the runway. Holding the nose up after touchdown for aerodynamic braking is not an effective braking technique and results in high nose gear sink rates upon brake application and reduced braking effectiveness.

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To avoid possible aircraft structural damage, do not make large nose down control column movements before the nose wheel is lowered to the runway.

To avoid the risk of a tail strike, do not allow the pitch attitude to increase after touchdown. However, applying excessive nose down elevator during landing can result in substantial forward fuselage damage. Do not use full down elevator. Use an appropriate autobrake setting or manually apply wheel brakes smoothly with steadily increasing pedal pressure as required for runway condition and runway length available. Maintain deceleration rate with constant or increasing brake pressure as required until stopped or desired taxi speed is reached.

Spoilers

CAUTION: If throttles are forward of the idle position during main wheel spin-up, the auto spoilers may not function. In this case the spoilers must be extended manually.

The spoilers can be fully raised after touchdown while the nose wheel is lowered to the runway, with no adverse pitch effects. The spoilers spoil the lift from the wings, which places the aircraft weight on the main landing gear, providing excellent brake effectiveness.

Unless spoilers are raised after touchdown, braking effectiveness may be reduced initially as much as 60%, since very little weight is on the wheels and brake application may cause rapid antiskid modulation. In addition, the autobrakes, if selected, will not function.

Normally, spoilers are armed to extend automatically. Both pilots should monitor spoiler extension after touchdown. The autospoiler actuator cycles every landing, even if the spoiler handle is not armed. Only visual confirmation of the spoiler handle in the up, aft, and latched position ensures ground spoiler deployment. Bounced landings, throttle forward of idle at touchdown, or unexpected system malfunctions may cause improper spoiler actuation. In the event auto extension fails, the captain must ensure the spoilers are extended manually.

Pilot awareness of the position of the spoiler lever during the landing phase is important in the prevention of over-run. The position of the spoilers should be announced during the landing phase by the PM. This improves the crew's situational awareness of the position of the spoilers during landing and builds good habit patterns which can prevent failure to observe a malfunctioned or disarmed spoiler system.

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Directional Control and Braking during Landing Roll

If the nose wheels are not promptly lowered to the runway, braking and steering capabilities are significantly degraded and no drag benefit is gained. On a dry runway, rudder control is effective to approximately 60 knots. Rudder pedal steering is sufficient for maintaining directional control during the rollout. Do not use the nose wheel steering wheel until reaching taxi speed. In a crosswind, displace the control wheel into the wind to maintain wings level which aids directional control. Perform the landing roll procedure immediately after touchdown. Any delay markedly increases the stopping distance.

Stopping distance varies with wind conditions and any deviation from recommended approach speeds.

Factors Affecting Landing Distance

Advisory information for normal and non-normal configuration landing distances is contained in the ODM. Normal information is also available through the LPR. Factors that affect stopping distance include: height and speed over the threshold, glide slope angle, landing flare, lowering the nose to the runway, use of reverse thrust, spoilers, wheel brakes, and surface conditions of the runway.

Note: Reverse thrust and spoiler drag are most effective during the high-speed portion of the landing. Deploy the speedbrake lever and activate reverse thrust with as little time delay as possible.

Floating above the runway before touchdown must be avoided because it uses a large portion of the available runway. The aircraft should be landed as near the normal touchdown point as possible. Deceleration rate on the runway is approximately three times greater than in the air.

Height of the aircraft over the runway threshold also has a significant effect on total landing distance. For example, on a 3° glide path, passing over the runway threshold at 100 feet altitude rather than 50 feet could increase the total landing distance by approximately 950 feet. This is due to the increased runway used before the aircraft actually touches down.

Reduced flaps landing increases landing distance by approximately 300 feet. Landing distance assumptions and performance can be determined by referencing the LPR or ODM.

Glide path angle also affects total landing distance. As the approach path becomes flatter, even while maintaining proper height over the end of the runway, total landing distance is increased.

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Non-Normal Landing Distance

Because of the higher approach speeds and the possible degraded capability of deceleration devices (spoiler, brakes, reversers) associated with the non-normal landing condition, the actual landing distance is increased. The Abnormal Configuration Actual Landing Distances table in the ODM shows VREF and landing distances for various non-normal landing configurations and runway conditions.

Slippery Runway Landing Performance

When landing on slippery runways contaminated with ice, snow, slush, or standing water, the reported braking action must be considered. Normal stopping distances for the various autobrake settings are available in the LPR, and both normal and non-normal configurations are provided in the ODM. Pilots should use extreme caution to ensure adequate runway length is available when poor braking action is reported.

CAUTION: (88) Select idle reverse for all landings on non-DRY runways.

CAUTION: (88) On runways with braking action less than good, delay thrust reverse deployment until nose wheel touchdown, so that directional control is less affected by asymmetric deployment.

Slippery/contaminated runway performance data is based on an assumption of uniform conditions over the entire runway. This means a uniform depth for slush/standing water for a contaminated runway or a fixed braking coefficient for a slippery runway. The data cannot cover all possible slippery/contaminated runway combinations and does not consider factors such as rubber deposits or heavily painted surfaces near the end of most runways.

Refer to the Vol. 1, SP.16 and the Airway Manual, Weather, Braking Action.

Landing on Wet or Slippery Runways

CAUTION: (88) When utilizing idle reverse thrust and full rudder deflection, the resultant rudder moment will be at least 65% of the full rudder moment experienced while utilizing forward thrust, regardless of the airspeed.
When utilizing 1.3 EPR reverse thrust and full rudder deflection, the resultant rudder moment caries from 57% at 150 kts. to 16% at 80 kts., when compared to the rudder moment experienced when utilizing forward thrust and full rudder deflection. The rudder effectiveness in this condition will continue to decrease as speed decreases.

CAUTION: Anticipate low friction when approaching touchdown zone at far end of runway due to heavy rubber and oil deposits.

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When it has been established that a safe landing can be made, the airplane must be flown with the objective of minimizing landing distance. The approach must be stabilized early. Precise control over drift and approach speeds is mandatory. Execute a missed approach if zero-drift condition cannot be established prior to touchdown. When making the transition to visual reference for landing, continue to utilize glideslope and VASI information to control the glidepath as wet windshields and snow-covered surfaces may distort depth perception. The airplane should be flown firmly onto the runway at the aiming point. Avoid holding off. Be prepared to manually deploy spoilers if automatic deployment does not occur as wheel spinup may be delayed.

On touchdown, take positive action to lower the nose wheel to the runway and maintain moderate forward pressure on control column to assist in directional control. Avoid excessive forward control column pressure in order to retain maximum braking effectiveness and to reduce possibility of nosewheel spray. Hydroplaning may cause delayed Auto Spoiler deployment. Be prepared to quickly manually deploy the spoilers. Simultaneously apply brakes and reverse thrust smoothly and symmetrically, as appropriate to the braking action and runway length available to ensure a safe stop. On wet, contaminated, or slippery runways, immediately after nose gear touchdown, maximize anti-skid braking operation by applying full brake pressure smoothly and symmetrically while applying reverse thrust to the idle reverse detent.

88

After reverse thrust symmetry is verified and the aircraft is aligned with the runway track, it is permissible to methodically and gradually increase reverse thrust to no greater than 1.3 EPR if required to reduce stopping distance.

90

After reverse thrust symmetry is verified, gradually increase reverse thrust. Reverse thrust should be applied smoothly and symmetrically to 1.3 EPR as soon as possible.

Reverse thrust effectiveness is greatest at higher speeds. Full brake pressure, and reverse thrust, should be maintained until a safe stop is assured. If auto brakes are used, consider selecting the MAX setting.

The use of reverse thrust may cause a visibility problem from blowing snow forward as ground speed decreases. Take action as appropriate for braking effectiveness and runway length available. Avoid rapid return to forward thrust when engine RPM is high. Resultant forward thrust may be high enough to cause airplane to accelerate. Avoid large abrupt steering inputs. Maintain directional control primarily with rudder pedals. Use differential braking as needed. Be alert for drift toward downwind side of the runway.

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The rudder required in strong crosswinds may cause the nose gear to turn to an angle which could induce skidding. Therefore, it may be necessary to hold the nose gear steering wheel centered while controlling steering with rudder and brakes to maintain tracking.

If a skid develops, especially in crosswind conditions, reverse thrust will increase the sideward movement of the airplane. If difficulty maintaining directional control is experienced during reverse thrust operation, reduce thrust to reverse idle (or forward idle thrust if required) regain directional control, and reapply reverse thrust as necessary. Apply rudder as necessary to realign the airplane with the runway and reapply braking and reversing to complete the landing roll. It is not necessary to immediately correct to runway centerline as this may delay deceleration efforts and aggravate skid conditions. Use as much runway as necessary to slow the airplane. Do not attempt to turn off a slippery runway until speed is reduced sufficiently to turn without skidding. Consider that braking effectiveness in the last 2,000 feet of the runway may be further reduced by painted surfaces and by accumulation of fuel, oil, and rubber. Consider leaving engines in idle reverse until ability to stop, or clear the runway, is assured.

Wheel Brakes

Braking force is proportional to the force of the tires on the runway and the coefficient of friction between the tires and the runway. The contact area normally changes little during the braking cycle. The perpendicular force comes from aircraft weight and any downward aerodynamic force such as spoilers.

The coefficient of friction depends on the tire condition and runway surface, (e.g. concrete, asphalt, dry, wet, or icy).

Automatic Brakes

Use of the autobrake system is recommend whenever the runway is limited, when using higher than normal approach speeds, landing on slippery runways, or landing in a crosswind.

For normal operation of the autobrake system select a deceleration setting.

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Settings include:

- MIN: Not recommended. Experience has shown that MIN brakes generate high brake temperatures contributing to excessive brake wear, and provide minimal braking capability.
- MED: Should be used for wet or slippery runways, when landing rollout distance is limited, reverser capability is reduced, or landing speed is higher than normal. (With combinations of these conditions, the use of MAX brakes is recommended). In the MED position, the ABS provides a three-second delay after spoiler deployment until brake application.
- MAX: Should be used when minimum stopping distance is required, e.g., cluttered, snow covered, icy, or wet ungrooved runways. In the MAX position, the ABS provides a one second delay after spoiler deployment until brake application. MAX autobrakes does not use a deceleration rate, but applies the brakes to the antiskid limit. Deceleration rate is less than that produced by full manual braking.

Note: The use of autobrakes is recommended because maximum autobraking may be more effective than maximum manual braking due to timely application upon touchdown and symmetrical braking. However, maximum manual braking provides the shortest stopping distance. If stopping distance is critical, consider using max autobrakes for the touchdown and quickly transitioning to max manual brakes to stop the aircraft.

Note: Do not delay lowering the nose gear to the runway after landing with MAX selected.

Experience with various runway conditions and the related aircraft handling characteristics provide initial guidance for the level of deceleration to be selected.

After main gear touchdown and once nose gear is on the runway, reverse thrust allows the autobrake system to reduce brake pressure. Since the autobrake system senses deceleration (MIN and MED only) and modulates brake pressure accordingly, the proper application of reverse thrust results in reduced braking for a large portion of the landing roll.

The importance of establishing the desired reverse thrust level as soon as possible after touchdown cannot be overemphasized. This minimizes brake temperatures and tire and brake wear, and reduces stopping distance on very slippery runways.

The use of minimum reverse thrust as compared to maximum reverse thrust can double the brake energy requirements and result in brake temperatures much higher than normal.

After touchdown, crewmembers should be alert for autobrake disengagement annunciations. The PM should notify the PF any time the autobrakes disengage.

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If stopping distance is not assured with autobrakes engaged, the PF should immediately apply manual braking sufficient to ensure deceleration to a safe taxi speed within the remaining runway.

The Operational Landing Distance charts, available via LPR and in the ODM, show the stopping capabilities of the available autobrake selections.

Transition to Manual Braking

The speed at which the transition from autobrakes to manual braking is made depends on airplane deceleration rate, runway conditions, and stopping requirements. Normally the spoilers remain deployed until clearing the runway. When transitioning to manual braking, use reverse thrust as required until taxi speed. The use of spoilers and reverse thrust is especially important when nearing the end of the runway where rubber deposits affect stopping ability.

When transitioning from the autobrake system to manual braking, the PF should notify the PM. Techniques for release of autobrakes can affect passenger comfort and stopping distance. These techniques are:

- Smoothly apply brake pedal force as in a normal stop, until the autobrake system disarms. Following disarming of the autobrakes, smoothly release brake pedal pressure. Disarming the autobrakes before coming out of reverse thrust provides a smooth transition to manual braking.
- PF directs the PM to manually position (step down) the autobrake selector through each lower setting until the autobrakes are selected off.

Manual Braking

The following technique for manual braking provides optimum braking for all runway conditions:

For a typical landing on a dry runway, consider delaying manual braking until 100 knots to reduce brake temperatures.

The pilot's seat and rudder pedals should be adjusted so that it is possible to apply maximum braking with full rudder deflection.

For short or slippery runways, use full brake pedal pressure.

- Do not attempt to modulate, pump, or improve the braking by any other special techniques
- Do not release the brake pedal pressure until the aircraft speed has been reduced to a safe taxi speed
- The antiskid system stops the aircraft for all runway conditions in a shorter distance than is possible with either antiskid off or brake pedal modulation.

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The antiskid system adapts pilot-applied brake pressure to runway conditions by sensing an impending skid condition and adjusting the brake pressure to each individual wheel for maximum braking. When brakes are applied on a slippery runway, several skid cycles occur before the antiskid system establishes the right amount of brake pressure for the most effective braking.

If the pilot modulates the brake pedals, the antiskid system is forced to readjust the brake pressure to establish optimum braking. During this readjustment time, braking efficiency is lost.

Low available braking coefficient of friction on extremely slippery runways at high speeds may be interpreted as a total antiskid failure. Pumping the brakes degrades braking effectiveness. Maintain steadily increasing brake pressure, allowing the antiskid system to function at its optimum.

Although immediate braking is desired, manual braking techniques normally involve a four-to five-second delay between main gear touchdown and brake pedal application even when actual conditions reflect the need for a more rapid initiation of braking. This delayed braking can result in the loss of 800 to 1,000 feet of runway. Directional control requirements for crosswind conditions and low visibility may further increase the delays. Distractions arising from a malfunctioning reverser system can also result in delayed manual braking application.

Although manual braking will provide a greater deceleration rate than MAX auto braking, MAX autobrakes will initially provide a more rapid and symmetrical brake application. When minimum stopping distance is required use MAX autobrakes and transition to maximum manual braking if required.

Carbon Brake Life

(90)

Carbon brake wear is primarily dependent upon the number of brake applications. For example, one firm brake application causes less wear than several light applications. Continuous light applications of the brakes to keep the aircraft from accelerating over a long period of time (riding the brakes) to maintain a constant taxi speed produces more wear than proper brake application.

During taxi, proper braking involves a steady application of the brakes to decelerate the aircraft. Release the brakes as lower speed is achieved. After the aircraft accelerates, repeat the braking sequence.

During landing, one hard, high energy, long-duration brake application produces the same amount of wear as a light, low-energy, short application. This is different from steel brakes that wear as a function of the energy input during the stop.

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Brake Cooling

A series of taxi-back or stop-and-go landings without additional in-flight brake cooling can cause excessive brake temperatures.The energy absorbed by the brakes from each landing is cumulative.

Extending the gear a few minutes early in the approach normally provides sufficient cooling for a landing.

Close adherence to recommended landing roll procedures ensures minimum brake temperature buildup.

Minimizing Brake Heat Build Up

Consider using the following technique if landing overweight or other factors exist that may lead to excessive brake temperatures. A normal landing, at weights up to maximum landing weight, does not require special landing techniques. In all cases including high ambient temperature or high density altitude brake temperatures can be reduced by delaying manual brake application to 100 knots or less.

Note: The aircraft is not certified to autoland at greater than maximum landing weight.

To minimize brake temperature buildup, use the following landing techniques:

- Complete the overweight landing checklist, if applicable (refer to QRH)
- Select the longest runway available but avoid landing downwind
- Use the largest available landing flap setting
- Although the autobrakes initially increase brake temperature, the brake contribution is minimized after reverser deployment
- Ensure all of the headwind additive is bled off before touchdown to avoid landing with excessive airspeed
- Use a normal gear touchdown aim point
- Do not allow the aircraft to float
- Ensure the spoilers deploy immediately after touchdown
- After main gear touchdown and with the nose tracking toward the runway, move the reverse levers to idle reverse. Upon nose wheel touchdown select 1.3 EPR reverse. The intention is to use reverse thrust as the major force that stops the aircraft. The use of 1.3 EPR reverse thrust further minimizes brake heating
- As soon as stopping is assured in the remaining runway, turn the autobrakes off and continue slowing the aircraft with reverse thrust
- If stopping in the remaining runway is in doubt, continue use of autobrakes or take over manually and apply up to maximum braking as needed

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- Consider extending the landing gear early to provide maximum brake cooling as needed
- If brake temperature is above (88) 305 or (90) 540, or BRAKE OVHT light remains illuminated, the brakes and tires require maintenance inspection before the next flight. If brake temperature exceeds gauge limits, loss of braking may occur.

Reverse Thrust Operation

CAUTION: (90) A 17-pound pull past the last stop will activate emergency reverse thrust. Activation of emergency reverse thrust results in an ENG SYS FAIL message and requires an extensive engine maintenance inspection.

WARNING: After reverse thrust is initiated, a full stop must be made.

Awareness of the position of the forward and thrust reverser levers must be maintained during the landing phase. Improper seat position as well as long sleeved apparel may cause inadvertent advancement of the forward throttles, preventing movement of the thrust reverser levers.

The palm of the hand should be resting on the throttle knobs. Maintaining the palm on the throttle provides better hand control and prevents high - and on the MD-90, inadvertent - emergency thrust activation.

Note: Reverse thrust is most effective at high speeds.

After main gear touchdown and once nose lowering has commenced thrust reversers should be deployed to reverse idle detent. Upon nosewheel touchdown and when the ENG REVERSE UNLOCK and ENG REVERSE THRUST lights illuminate increase reverse thrust as required. The PM should monitor engine operating limits and call out any engine operational limits being approached or exceeded, any thrust reverser failure, or any other abnormalities.

Maintain reverse thrust as required, up to maximum, until 80 knots. At this point start reducing the reverse thrust so that the thrust reverser levers are moving down at a rate commensurate with the deceleration rate of the aircraft. The reversers should be positioned to reverse idle by 60 knots, then to full down after the engines have decelerated to idle. Reverse thrust is reduced to idle between 80 knots and 60 knots, unless required for adverse conditions, to prevent engine surge and to reduce the risk of FOD. It also helps the pilot maintain directional control in the event a reverser becomes inoperative. The use of high levels of reverse thrust at low airspeeds and/or the rapid forward movement of thrust reverser levers when deselecting reverse thrust may cause engine stalls (surges) and contribute to reverse asymmetry.

Note: If an engine surges during reverse thrust operation, quickly select reverse idle on both engines.

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The PM should call out 80 knots to assist the PF in scheduling the reverse thrust. The PM should also call out any inadvertent selection of forward thrust as reverse thrust is canceled.

Note: Normal dry runway reverse thrust target is 1.3 EPR.

Note: The JT8 and V2500 engine fan blades can make contact with the fan blade rub strips causing sparks, which can be seen from the cabin. This can happen during any phase of flight but is most prevalent during reverse thrust and is especially noticeable at night. Rub strip sparking is part of the normal operation of the engines.

Note: (90) Activation of emergency reverse thrust results in an ENG SYS FAIL message; this requires an extensive thrust reverser maintenance inspection, which typically reveals engine damage.

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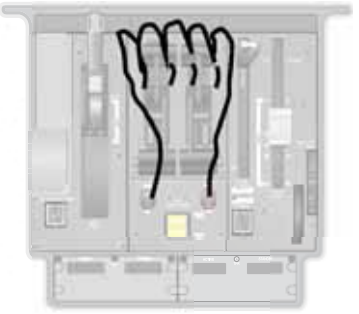
Reverse Thrust Operations

After main gear touchdown and once nose lowering has commenced, raise reversers up and aft to the idle stop.



Gripping Pattern

Use normal reverse until 80 KIAS.

By 80 KIAS initiate movement of reverse thrust levers to reach the reverse idle detent by 60 KIAS.

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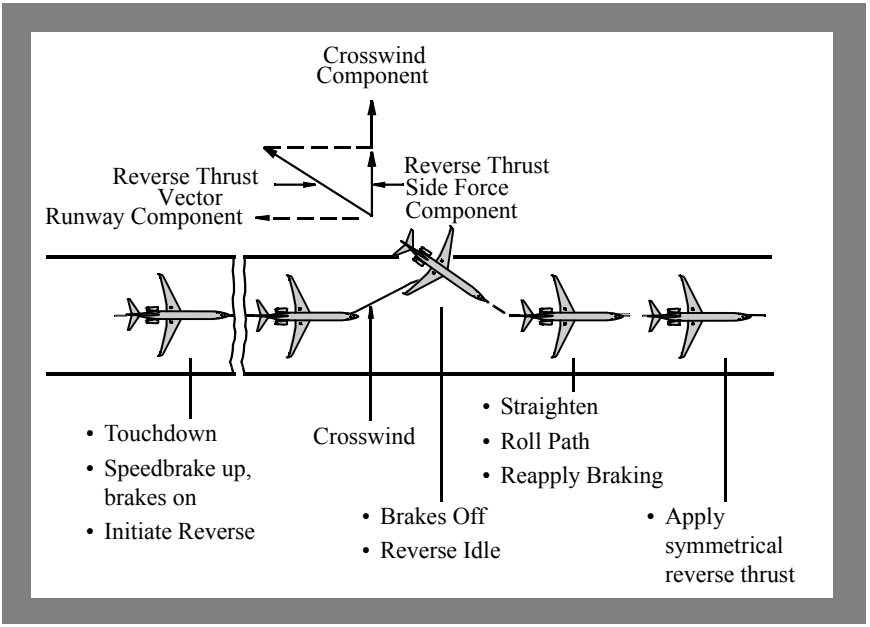
Reverse Thrust and Crosswind (All Engines)



This figure shows a directional control problem during a landing rollout on a slippery runway with a crosswind. As the aircraft starts to weathervane into the wind, the reverse thrust side force component adds to the crosswind component and drifts the aircraft to the downwind side of the runway. Also, high braking forces reduce the capability of the tires to corner.

To correct back to the centerline, release the brakes and reduce reverse thrust to reverse idle. Releasing the brakes increases the tire-cornering capability and contributes to maintaining or regaining directional control. Setting reverse idle reduces the reverse thrust side force component without the requirement to go through a full reverser actuation cycle. Use rudder pedal steering and differential braking as required to prevent over correcting past the runway centerline. When directional control is regained and the aircraft is correcting toward the runway centerline, apply maximum braking and symmetrical reverse thrust to stop the aircraft.

Note: Use of this technique increases the required landing distance.

Reverse Thrust - Engine Inoperative

Asymmetrical reverse thrust may be used with one engine inoperative. Use normal reverse thrust procedures and techniques with the operating engine. If directional control becomes a problem during deceleration, return the throttle to the reverse idle detent.

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Crosswind Landings

Note: For additional information on crosswind guidelines, refer to Vol. 1, SP.16, Guidelines for Takeoff on Contaminated Runways or Landing with Braking Action Less than Good.

Crosswind Landing Guidelines

The crosswind guidelines were derived through flight test data, engineering analysis, and flight simulator evaluations. These crosswind guidelines are based on steady wind (no gust) conditions and include all engines operating and engine inoperative. Gust effects were evaluated and tend to increase pilot workload without significantly affecting the recommended guidelines.

Crosswind Landing Techniques

Two methods of performing crosswind landings are presented. They are the de-crab technique (with removal of crab in flare), and the sideslip technique. Whenever a crab is maintained during a crosswind approach, offset the flight deck on the upwind side of centerline so that the main gear touches down in the center of the runway.

De-Crab During Flare

The objective of this technique is to maintain wings level throughout the approach, flare, and touchdown. On final approach, a crab angle is established with wings level to maintain the desired track. Just prior to touchdown while flaring the aircraft, downwind rudder is applied to eliminate the crab and align the aircraft with the runway centerline.

As rudder is applied, the upwind wing sweeps forward, developing roll. Hold wings level with simultaneous application of aileron control into the wind. The touchdown is made with cross controls and both gear touching down simultaneously. Throughout the touchdown phase upwind aileron application is utilized to keep the wings level.

Sideslip (Wing Low)

The sideslip crosswind technique aligns the aircraft with the extended runway centerline so that main gear touchdown occurs on the runway centerline.

The initial phase of the approach to landing is flown using the crab method to correct for drift. Prior to the flare the aircraft centerline is aligned on or parallel to the runway centerline. At approximately 200 feet AGL, downwind rudder is used to align the longitudinal axis to the desired track as aileron is used to lower the wing into the wind to prevent drift. A steady sideslip is established with opposite rudder and low wing into the wind to hold the desired course.

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Touchdown is accomplished with the upwind wheels touching just before the downwind wheels. Overcontrolling the roll axis must be avoided because overbanking could cause the wing tip to contact the runway. Refer to Bank Angle Limitations for Various Pitch Attitudes charts, this chapter.

Properly coordinated, this maneuver results in nearly fixed rudder and aileron control positions during the final phase of the approach, touchdown, and beginning of the landing roll. However, since turbulence is often associated with crosswinds, it is often difficult to maintain the cross control coordination through the final phase of the approach to touchdown. Ailerons will have increased effectiveness (sensitivity) in ground effect. Avoid over-controlling.

Overweight Landing

Overweight - General

Overweight landings may be safely accomplished by using normal landing procedures and techniques. There are no adverse handling characteristics associated with overweight landings. Landing distance is normally less than takeoff distance for flaps 28 or 40 landings at all gross weights. However, wet or slippery runway field length requirements should be verified from the landing distance charts in the ODM.

If stopping distance is a concern, reduce the landing weight as much as possible. At the captain's discretion, reduce weight by holding at low altitude with a high drag configuration (gear down) to achieve maximum fuel burn-off.

Observe flap placard speeds during flap extension and on final approach. In the holding and approach patterns, maneuvers should be flown at the normal maneuver speeds.

Use the longest available runway, and consider wind and slope effects. Where possible avoid landing in tailwinds, on runways with negative slope, or on runways with less than normal braking conditions. Do not carry excess airspeed on final. This is especially important when landing during an engine inoperative or other non-normal condition.

Fly a normal profile. Ensure that a higher than normal rate of descent does not develop. Do not hold the aircraft off waiting for a smooth landing. Fly the aircraft onto the runway at the normal touchdown point. If a long landing is likely to occur, go-around. After touchdown, immediately apply maximum reverse thrust using all of the available runway for stopping to minimize brake temperatures. Do not attempt to make an early runway turnoff.

Autobrake stopping distance guidance is contained in the ODM. If adequate stopping distance is available based upon approach speed, runway conditions, and runway length, the recommended autobrake setting should be used.

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Overweight Autolands

Overweight autolands are not recommended. Autopilots are not certified for automatic landings above maximum landing weight. At higher than normal speeds and weights, the performance of these systems may not be satisfactory and has not been thoroughly tested. An automatic approach may be attempted, however the pilot should disengage the autopilot prior to flare height and accomplish a manual landing.

In an emergency, should the pilot determine that an overweight autoland is the safest course of action, the approach and landing should be closely monitored by the pilot and the following factors considered:

- Touchdown may be beyond the normal touchdown zone; allow for additional landing distance
- Touchdown at higher than normal sink rates may result in exceeding structural limits
- Plan for a go-around or manual landing if autoland performance is unsatisfactory; automatic go-arounds can be initiated until just prior to touchdown, and can be continued even if the aircraft touches down after initiation of the go-around.

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Maneuvers
Table of Contents

Acceleration to and Deceleration from VMO 7.1

Engine Out Familiarization 7.2
Rudder and Lateral Control 7.2
Thrust and Airspeed 7.3

High Altitude Maneuvering, "G" Buffet 7.4
Mach Buffet 7.4
Mach Tuck 7.4
Dutch Roll 7.5
Mach Trim Compensator (MTC), Mach Buffet, Dutch Roll Demonstrations 7.5

Emergency Descent 7.6
Autopilot Entry and Level Off 7.7
Manual Entry and Level Off 7.7
After Level Off 7.8

Flight Control Effectiveness 7.9
Ailerons 7.9
Horizontal Stabilizer and Elevators 7.9
Rudder 7.9
Strakes 7.9
Vortilons 7.10
Flight Control Effectiveness Maneuvers 7.10

Autospoiler/Autobrake Demonstration 7.13

Stall or Approach to Stall 7.14
Stall or Approach to Stall Recovery Maneuver 7.14
Stall or Approach to Stall Characteristics 7.17
Stall or Approach to Stall Recovery 7.18

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Steep Turns 7.20
Entry 7.20
During Turn 7.20
Attitude Indicator 7.20
Vertical Speed Indicator 7.20
Altimeter 7.20
Airspeed 7.21
Rollout 7.21

Terrain Avoidance 7.22
Terrain Avoidance Maneuver 7.22

Traffic Alert and Collision Avoidance System 7.24
Traffic Advisory 7.24
Resolution Advisory 7.24
The RA Maneuver 7.24
Parallel Approach Exception to Resolution Advisory Compliance 7.26
Interaction with ATC 7.26
Mode of Operation 7.26
Other Considerations 7.27

Upset Recovery 7.28
General 7.30
Upset Recovery Techniques 7.33

Windshear 7.34
General 7.34
Avoidance 7.34
Precautions 7.34
Aircraft Performance in Windshear 7.36
Windshear Encounter Recognition 7.37
Windshear Escape Maneuver 7.37
Windshear During Takeoff Roll 7.38

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Windshear In Flight. 7.39
Post Windshear Considerations. 7.39

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Acceleration to and Deceleration from VMO

Acceleration to and deceleration from VMO demonstrates performance capabilities and response to speed, thrust, and configuration changes throughout the medium altitude speed range of the aircraft. This maneuver is performed in the full flight simulator/flight training device and is for demonstration purposes only. It is normally performed at 10,000 to 15,000 feet, simulating slowdown to 250 knots due to speed restrictions.

VMO is a structural limitation and is the maximum operating indicated airspeed. It is a constant airspeed from sea level to the altitude where VMO and MMO coincide. MMO is the structural limitation above this altitude. Sufficient thrust is available to exceed VMO in level flight at lower altitudes. Failure to reduce to cruise thrust in level flight can result in excessive airspeed.

Begin the maneuver at existing cruise speed with the autothrottle connected and the autopilot disengaged. Set command speed to VMO. As speed increases observe:

- Nose down trim required to keep aircraft in trim and maintain level flight
- Handling qualities during acceleration
- Autothrottle protection at VMO.

At a stabilized speed just below VMO execute turns at high speed while maintaining altitude. Next, accelerate above VMO by disconnecting the autothrottle and increasing thrust.

When the overspeed warning occurs reduce throttles to idle, set command speed to 250 knots, and decelerate to command speed. Since the aircraft is aerodynamically clean, any residual thrust results in a longer deceleration time. As airspeed decreases observe that nose up trim is required to keep aircraft in trim and maintain level flight. During deceleration note the distance traveled from the time the overspeed warning stops until reaching 250 knots.

Once stabilized at 250 knots, set command speed to flaps up maneuver speed and decelerate to command speed, again noting the distance traveled during deceleration. Observe the handling qualities of the aircraft during deceleration.

This maneuver may be repeated using speedbrakes to compare deceleration times and distances. Deploying the speedbrakes produces some buffeting and a pitch down tendency. Retraction of the speedbrakes results in a pitch up.

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Engine Out Familiarization

The exercises shown in the following table are performed to develop proficiency in handling the aircraft with one engine inoperative and gain familiarization with rudder control requirements.

	Condition One	Condition Two
Airspeed	Flaps up maneuver speed	V2
Landing Gear	Up	Down
Flaps	Up	11
Thrust	As Required	MCT
When In Trim - Retard one throttle to idle Controls - Apply to maintain heading, wings level Rudder - Apply to center control wheel Airspeed - Maintain with thrust (Condition One) Pitch (Condition Two) Trim - As required to relieve control forces		

One engine out controllability is excellent during takeoff roll and after lift-off. Minimum control speed in the air is below VR and VREF.

Rudder and Lateral Control

This familiarization is performed to develop proficiency in handling the aircraft with an engine inoperative. It also helps to gain insight into rudder control requirements.

Under instrument conditions the instrument scan is centered around the attitude indicator. Roll is usually the first indication of an asymmetric condition. Roll control (ailerons) should be used to hold the wings level or maintain the desired bank angle. Stop the yaw by smoothly applying rudder at the same rate that thrust changes. When the rudder input is correct, very little control wheel displacement is necessary. Refine the rudder input as required and trim the rudder so the control wheel remains approximately level.

When the rudder is trimmed to level the control wheel, the aircraft maintains heading. A small amount of bank toward the operating engine may be noticeable on the bank indicator. The slip/skid indicator is displaced slightly toward the operating engine.

If the aircraft is trimmed with too much control wheel displacement, full lateral control is not available and spoilers on one wing may be raised, increasing drag.

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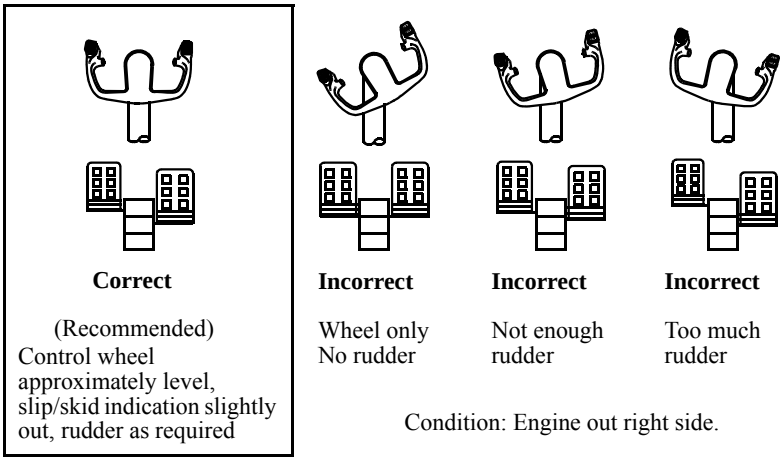
Make turns at a constant airspeed and hold the rudder displacement constant. Do not attempt to coordinate rudder and lateral control in turns. Rudder pedal inputs produce roll due to yaw and induce the pilot to counter rudder oscillations with opposite control wheel.

The following figure shows correct and incorrect use of the rudder.

If an engine failure occurs with the autopilot engaged, manually position the rudder to approximately center the control wheel and add thrust. Trim the rudder to relieve rudder pedal pressure.



Thrust and Airspeed

If not thrust limited, apply additional thrust, if required, to control the airspeed. The total two-engine fuel flow existing at the time of engine failure may be used initially to establish a thrust setting at low altitude. If performance limited (high altitude), adjust aircraft attitude to maintain airspeed while setting maximum continuous thrust.

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High Altitude Maneuvering, "G" Buffet

Aircraft buffet reached as a result of aircraft maneuvering is commonly referred to as “g” buffet. During turbulent flight conditions, it is possible to experience high altitude “g” buffet at speeds less than MMO. In training, buffet is induced to demonstrate the aircraft's response to control inputs during flight in buffet.

Note: Stick shaker is close to initial buffet for all weights and altitudes. Stick shaker activation may occur if the airplane is maneuvered beyond buffet.

Establish an airspeed of 0.80M. Induce “g” buffet by smoothly increasing the bank angle until the buffet is noticeable. Increase the rate of descent while increasing the bank angle to maintain airspeed. Do not exceed 45°of bank. If buffet does not occur by 45° of bank, increase control column back pressure until buffet occurs. When buffet is felt, relax back pressure and smoothly roll out to straight and level. Notice that the controls are fully effective at all times.

Mach Buffet

As altitude and airspeed increase, a flight condition will eventually be reached where the localized airflow becomes supersonic (Mach1.0) on top of the wing and weak shock waves begin to form. This condition occurs well below an actual aircraft Mach number of 1.0 and varies with flight level and aircraft weight. Although small, weak shock waves form on the wing at Mach 0.75, noticeable buffeting does not occur on the MD-88/90 until approaching MMO. At this Mach number, shock waves become quite large and strong, and move rapidly fore and aft on the wing, causing a gentle, high-frequency buffet. Buffet intensity will be significantly increased by making a turn, or by applying a slight back pressure to the control column. If the aircraft is accelerated beyond MMO, or if excessive g loading is applied, buffet intensity can increase enough to pose structural integrity problems.

Mach Tuck

In normal subsonic flight, the center of pressure (lift) on the wing is near the 1/4 chord point of the wing (approximately 25% of the way back on the wing from the leading edge). Although the airfoil center of pressure moves aft in the subsonic speed range as speed is increased, other factors, primarily the pitching moment created by the horizontal stabilizer, create a net pitch up tendency. This tendency is desirable, since any increase in speed will be naturally opposed by the aircraft. In the transonic range, however, due to shock wave formation and the associated loss of downwash on the horizontal stabilizer, and the rapidly increased aft movement of the wing center of pressure, a new pitch-down moment results. Mach tuck will become noticeable at Mach 0.80; and the pull force required to maintain level flight increases linearly up to Mach 0.85, then remains constant. The tuck effect is automatically zeroed by Mach trim compensation.

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Dutch Roll

Dihedral is considered to be positive when the wing tips are higher than the roots. The effect of dihedral is to produce a rolling moment tending to return the airplane to a balanced flight condition if sideslip occurs. Sweepback increases the dihedral stability of an aircraft, which to the pilot means the ability to pick up a wing by using opposite rudder. The dihedral stability is low for a sweptback-wing aircraft in the approach/landing configuration and also at very high Mach numbers.

An increase in wing sweepback normally degrades lateral-directional dynamic stability, better known as “Dutch Roll”. Dutch Roll is a combination of roll and yaw oscillations that are coupled together. As with most large, high-speed aircraft, there is a lateral directional oscillation present that may be excited by turbulence or rough use of the controls. With the yaw damper operative, all Dutch Roll oscillations are promptly dampened. If the yaw damper should become inoperative, Dutch Roll may be easily dampened with the primary flight controls. Recommended procedure is to use aileron to stop the roll. The oscillations have a relatively long period and the pilot should experience no difficulty in timing control inputs to dampen the oscillation.

Mach Trim Compensator (MTC), Mach Buffet, Dutch Roll Demonstrations

These maneuvers can be performed in the full flight simulator and are used for demonstration purposes only.

Set MCT power, lower nose of aircraft and accelerate until buffet. Note movement of the MTC indicator rod (MD-88) / longitudinal trim indicator (MD-90). Reduce speed to 0.82M. Place MTC switch to OVRD (MD-88) / OFF (MD-90). Note force required to maintain that speed. Allow aircraft to return to level flight. Place MTC switch to NORM. With speed at 0.72-0.74M, Yaw Damper OFF, and wings level, place aircraft in shallow climb. Apply rudder pressure sufficient to displace slip indicator with maximum bank angle of 15°. Recover to wings level by opposing rising wing. Keep rudder centered. Neutralize ailerons when wings are level. Apply aileron correction at the same rate as Dutch Roll oscillations. Repeat entry procedure. Move Yaw Damper switch to ON and note reduced oscillations.

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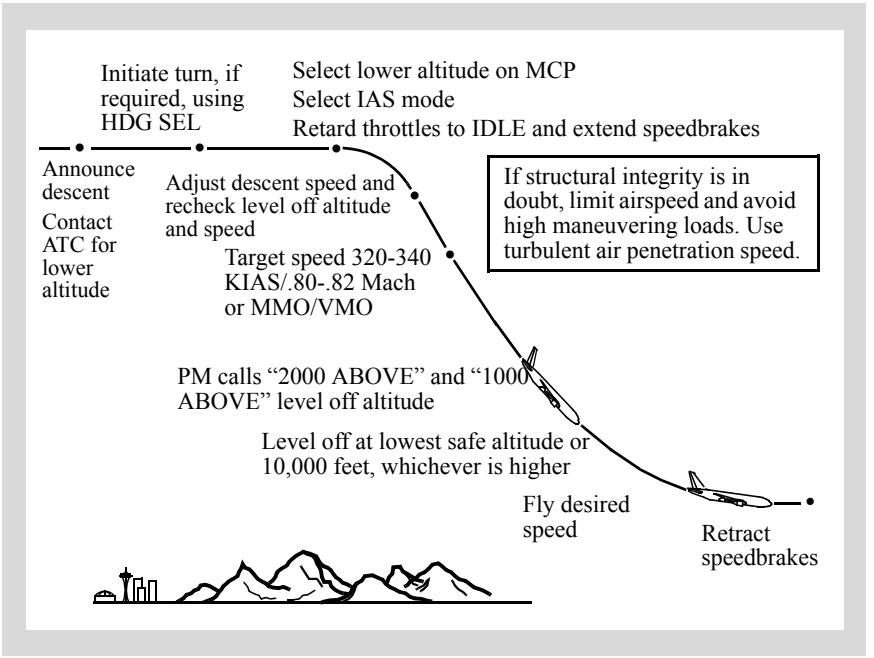
Emergency Descent

This section addresses basic techniques and procedures for a emergency descent. Some routes over mountainous terrain require careful planning to include carrying additional oxygen, special procedures, higher initial level off altitudes, and emergency routes in the event a depressurization is experienced.

This maneuver is designed to bring the aircraft down smoothly to a safe altitude, in the minimum time, with the least possible passenger discomfort.

Note: Use of the autopilot is recommended.

Emergency Descent Profile



If the descent is performed because of a rapid loss of cabin pressure, crewmembers should place oxygen masks on and establish communication at the first indication of a loss of cabin pressurization. Verify cabin pressure is uncontrollable, and if so, begin descent. If structural damage exists or is suspected, limit airspeed to current speed or less. Avoid high maneuvering loads.

Perform the maneuver deliberately and methodically. Do not be distracted from flying the aircraft. If icing conditions are entered, use anti-ice and thrust as required.

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In airspace/airways with reduced vertical separation coupled with improved navigation accuracy, due to the close lateral separation of airplanes below cruise altitude, descending before turning may not be practical. In this case an immediate turn may be appropriate.

Note: Emergency descents are normally made with the landing gear up.

The PM checks the lowest safe altitude, notifies ATC, and obtains an altimeter setting (QNH). Both pilots should verify that all memory items have been accomplished and call out any items not completed. The PM calls out 2,000 feet and 1,000 feet above the level-off altitude.

Level off at the lowest safe altitude or 10,000 feet, whichever is higher. Lowest safe altitude is the Minimum Enroute Altitude (MEA), Minimum Off Route Altitude (MORA), or any other altitude based on terrain clearance, navigation aid reception, or other appropriate criteria.

If severe turbulent air is encountered or expected, reduce to the turbulent air penetration speed.

Autopilot Entry and Level Off

Because of airspeed and altitude protection and reduced crew workload, use of the autopilot with IAS mode is the best practice for emergency descents.

Set a lower altitude in the altitude window. Select IAS, retard the throttles to idle and extend the speedbrakes. Fly straight ahead or initiate a turn using HDG SEL. Leave autothrottles engaged. The airplane will pitch down smoothly when the throttles are retarded to idle. Adjust the speed as necessary and ensure the altitude window is correctly set for the level off. During descent, the IAS/MACH speed window does not automatically change from MACH to IAS. The use of IAS (not MACH) will help prevent overspeed warnings.

When approaching the target altitude, ensure the altitude is set in the MCP altitude select window. Altitude capture engages automatically. Adjusting the command speed prior to level-off aids in smoothly transitioning to level flight. Do not adjust the pitch wheel during altitude capture. The pitch mode then controls altitude and the throttles increase to hold the selected speed. Smoothly retract the speedbrakes during the level off maneuver.

Manual Entry and Level Off

The entry may be accomplished on heading or a turn may be made to clear the airway or controlled track. However, since extending the speedbrakes initially reduces the maneuver margin, monitor the airspeed indicator and bank angle to ensure that at least minimum maneuver speed is maintained when turning.

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To manually fly the maneuver, disconnect the autopilot and autothrottles. Smoothly lower the nose to initial descent attitude of approximately 10° nose down. Retard the throttles to idle and smoothly extend the speedbrakes.

About 10 knots before reaching target speed, slowly raise the pitch attitude to maintain target speed. Keep the aircraft in trim at all times. If MMO/VMO is inadvertently exceeded, change pitch smoothly to decrease speed.

Approaching level-off altitude, smoothly adjust pitch attitude to reduce rate of descent. The speedbrake lever should be retracted when approaching the desired level-off altitude.

After Level Off

Recheck the pressurization system and evaluate the situation. Do not remove the crew oxygen masks if cabin altitude remains above 10,000 feet.

Note: Determine the new course of action based on weather, oxygen, fuel remaining, medical condition of crew and passengers, terrain and available airports. Obtain a new ATC clearance.

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Flight Control Effectiveness

Primary flight controls consist of aileron, rudder, and elevator control systems. Secondary flight controls consist of leading edge slats, flight and ground spoilers, inboard and outboard flaps, and horizontal stabilizer. The ailerons and elevators are normally operated mechanically (MD-90 elevators are hydraulic). The ailerons have hydraulically assisted flight spoilers for roll control. The rudder is normally hydraulically powered. In the event of a total hydraulic power loss, the primary flight controls are fully operational.

Ailerons

The ailerons are bussed together by cables and driven aerodynamically by control tabs. The control tabs are connected by cable to the control wheel. The ailerons are not powered in any way. However, rolling forces induced by aileron inputs are supplemented by hydraulically actuated spoilers on each wing surface. Movement of the control wheel beyond approximately 5° will cause the spoilers to extend.

Horizontal Stabilizer and Elevators

Longitudinal trim is accomplished by changing the angle of incidence of the horizontal stabilizer. It is effective throughout the entire center of gravity range and speed envelope of the aircraft. As the stabilizer is moved, the elevator forces must be relaxed to maintain the same attitude. Aerodynamic response induced by movement of the horizontal stabilizer is about 2½ times greater than that induced by elevator movement through the same angular deflection. Primary pitch control is obtained by movement of the elevators.

Rudder

Normally the rudder will be operated at all times in the power mode. Rudder effectiveness is more than adequate under all flight conditions including single-engine operation and autoland operation with rudder power on. With rudder power off (manual rudder or restricted rudder), during single-engine operation, the VMCA may be as high as 135 KIAS.

Strakes

Fuselage strakes are added at the nose to enhance directional control (rudder) during high angle of attack flight. Engine strakes are added to the engine nacelles to enhance longitudinal (elevator) control for post stall recovery.

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Vortilons

The vortilons (Vortex-Generating Pylons) serve a dual purpose. First, because of their size, shape, and location, there is a significant effect on the tail surfaces at high angles of attack. This action enhances aerodynamic response from the tail surfaces below the stalling speed of the aircraft (the tail is still flying after the aircraft initially stalls). The secondary purpose is to act as an aerodynamic fence, which contributes to a positive and stable restoring moment in stall recovery. During development of the original DC-9, wind tunnel tests indicated that spanwise flow on the wing caused the outboard portion of the wing to begin stalling early resulting in some minor pitch up at stall. The solution was the vortilon. The device is shaped such that the wing stagnation point in the normal flight envelope is ahead of the vortilon leading edge and no vortex drag penalty is induced at these conditions. At angles of attack approaching stall, the stagnation point moves aft of the intersection and a strong vortex is created over the top of the wing. This energizes the outer panel boundary layer and delays outer panel stall. The vortex then continues aft, rotating in a manner that creates an upwash field at the tail that adds to the pitch down forces at, and substantially beyond stall.

Flight Control Effectiveness Maneuvers

These maneuvers are performed in the full flight simulator and are for demonstration purposes only.

Proper aircraft flight dynamics and handling qualities are a function of timely, appropriate, and coordinated flight control inputs. Whether teaching recoveries from stall, CFIT, windshear or upsets, the expected norm is coordinated flight to the maximum extent possible. In order to establish a baseline for coordinated flight, Delta Air Lines presents three demonstrations to the initial qualification pilot. These are one-time demonstration/practice and intended to show the power of the flight controls (i.e. handling quality) and aerodynamic response (i.e. flight dynamic) of the aircraft. These demonstrations are accomplished at approach airspeeds representative of typical maneuver energy states and intermediate wing angle of attack. These maneuvers are:

- Rudder effectiveness demonstration
- Aileron effectiveness demonstration
- Loaded/unloaded roll demonstration.

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Rudder Effectiveness

This maneuver is accomplished with hands off (hands placed behind the control column, allowing pitch inputs only) the control yoke using rudder inputs only to induce a roll to 45° of bank and return to wings level. The emphasis is on smooth, incremental application of rudder. Focus should be on rate of application and magnitude of rudder input. Properly done (slow, incremental) the aircraft will roll to dihedral effect with minimal adverse yaw. Improperly done (fast, large amplitude) the aircraft will display adverse yaw and roll coupling. Only a small amount of rudder input is needed (to induce a roll). Too much rudder applied too quickly or held too long may result in loss of lateral and directional control. Rudder is never the preferred initial response to induce a roll in a transport category aircraft.

Aileron Effectiveness

In like manner, the aileron effectiveness demonstration is accomplished in one axis (aileron roll only with feet off rudder pedals) at approach energy states and angle of attack. The pilot will smoothly roll to 60° bank and then roll back to wings level using full throw aileron authority. The instructional intent is to allow the pilot to observe full throw aileron position, authority, and the generated roll rate and roll overshoots (roll out lead points change) as the wings approach level. Additionally, any asymmetric tendencies caused by differential aileron and/or spoiler deployment will be evident.

This demonstration accomplishes three objectives. First, it demonstrates the aircraft will not depart controlled flight from full throw aileron applications. Second, it establishes a baseline in the student's mind for roll rate capability at an approach energy state. Third, it demonstrates roll overshoot tendencies inherent with large aileron deflection rolls. This level of roll demand would only be required when responding to an unanticipated departure of the aircraft in roll (e.g. wake turbulence, partial flap failure, asymmetric loss of flap structure, etc.).

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Loaded/Unloaded Roll

The previous maneuvers are tied together in a coordinated training event utilizing all three axes. This exercise will also demonstrate the effectiveness of a slight release of backpressure to activate the roll mode using aileron. The pilot will smoothly roll to 60° (approximately) of bank, then pull (smoothly) to stick shaker. Recover in the following three manners:

- Roll with ailerons only without the use of rudder and no release of backpressure. The result will be a slow roll to wings level.
- Roll with ailerons only and small release of backpressure. No use of rudder. The result will be improved roll rate to wings level.
- Roll using aileron and small release of backpressure and coordinated input of rudder. The result will be improved roll rate to wings level with yaw coordination.

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Autospoiler/Autobrake Demonstration

This maneuver is performed in the full flight simulator and is for demonstration purposes only. The objective is to demonstrate autospoiler and autobrake operation and show methods in which they may be disarmed. A series of three landings is performed, each landing commencing from short final. The PF will fly the aircraft to touchdown and smoothly lower the nose to the runway and will not apply manual braking and will not pull thrust reverse thrust. The pilot monitoring will manipulate the spoilers, flaps, and throttles. Autobrakes will be set to MAX for best effect.

- After the first landing and the nosewheel on the runway, feel the autobrakes engage in MAX. Pilot monitoring will place the flaps to 15. Note the disarming on the autobrakes (yellow ABS light) and feel the brakes release.
- Reposition to final with autobrakes and autospoilers failed simulating an autospoiler failure or a severe hydroplaning condition. After the nosewheel is on the runway, the pilot monitoring deploys the spoilers by pulling the handle straight back. Then, with the spoiler handle locked back, the pilot monitoring advances the right throttle until the autobrakes disarm (yellow ABS light) and the brakes release. When this occurs the pilot monitoring will pull the right throttle to idle and then will advance the left throttle slowly until the autospoilers disarm.
- Reposition to final with autobrakes armed and autospoilers disarmed. The PF lands again in the same manner. After the nosewheel is on the runway, the pilot monitoring deploys the spoilers manually (up back and up). After the autobrakes have activated, the pilot monitoring will disarm the spoilers. Note the brake pressure releases but the autobrakes do not disarm (yellow ABS light does not come on). Redeploy the spoilers and note the brakes reapply. Repeat as necessary until fully stopped.
- After fully stopped, arm the spoiler handle. The pilot monitoring pulls the thrust reverser levers up and the spoilers deploy. Disarm the spoilers and deploy them manually, only this time after pulling up and back about 1-2 inches, push the handle down and continue to pull back (the pilot monitoring will have to hold the handle back as the spoilers are deployed but in the disarm channel and not full up in the locking position). Release the handle and watch it return to the stowed position. Repeat the exercise and pull the handle full up after it is full back thus locking the handle full aft. The purpose of this demonstration is to show the two channels the ground spoilers may operate in during deployment and the reason for the up back and up technique to manually deploy and lock the spoilers.

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Stall or Approach to Stall

Stall or Approach to Stall Recovery Maneuver

WARNING: During takeoff, a stick shaker, STALL warning light, horn, or "STALL" aural warning at rotation may indicate an improper FLAP/SLAT configuration. PF immediately call out "SLATS EXTEND," PM confirm "SLATS EXTENDED."

If conditions permit, accept an altitude loss while accelerating to an appropriate speed for existing configuration.

Note: Do not use flight director commands during the recovery.

Note: Premature recovery may result in a secondary stall or inability to accelerate with thrust available.

Immediately do the following at the first indication of stall warning (buffet or stick shaker).

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Pilot Flying	Pilot Monitoring
Initiate the recovery: **WARNING: In some cases, control column may not immediately provide needed pitch response. In such cases, it may be necessary to apply up to full forward control input, enhancing that input with pitch trim if necessary.** **WARNING: Only a small amount of rudder is needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control.** • Hold control column firmly Simultaneously, • **88** Disconnect autopilot and autothrottles. Apply takeoff/ go-around or MCT thrust as applicable. If ground contact is imminent, apply thrust to mechanical stops. • **90** Disconnect autopilot and autothrottle. Apply maximum thrust to N1 mode gate. If ground contact is imminent, apply thrust through N1 mode gate to mechanical stop (maximum available thrust) • Reduce angle of attack by applying nose down elevator until buffet and stick shaker stop.	• Monitor altitude and airspeed. • Verify all required actions have been accomplished and call out any omissions. • Call out any trend toward terrain contact.

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Pilot Flying	Pilot Monitoring
Continue the recovery: • If in a turn, roll in the shortest direction to, and maintain, wings level. • Confirm speed brakes stowed. • If conditions permit, accept an altitude loss while accelerating to an appropriate speed for existing configuration. • If flaps/slats or landing gear are extended, do not change configuration during stall recovery.	• Monitor altitude and airspeed. • Verify all required actions have been accomplished and call out any omissions. • Call out any trend toward terrain contact.
Complete the recovery: • Accelerate to an appropriate speed for existing speed for existing configuration, then adjust configuration as desired. Return to appropriate altitude and airspeed. • Re-engage autopilot and autothrottles if desired.	• Monitor altitude and airspeed. • Verify all required actions have been accomplished and call out any omissions. • Call out any trend toward terrain contact.

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Stall or Approach to Stall Characteristics

An approach to a stall is a controlled flight maneuver; a stall is an out-of-control, but recoverable, condition. However, the recovery maneuver is the same for either an approach to a stall or a fully developed stall.

Most approach to stall incidents have occurred where there was altitude available for recovery. The incidents that progressed into accidents often occurred because the crew failed to make a positive recovery when the stall warning occurred, the condition progressed to a full stall, and the aircraft impacted the ground in a stalled condition. For this reason, emphasis has shifted from a recovery with minimum loss of altitude to reducing the angle of attack below the wing stalling angle to complete a positive and efficient recovery.

During initial stages of stall, local airflow separation results in buffeting (initial buffet), giving natural warning of an approach to stall. A stall warning is considered to be any warning readily identifiable by the pilot, either artificial (stick shaker, auto slat extended) or initial buffet. Recovery from an approach to stall is initiated at the earliest recognizable stall warning, initial buffet or stick shaker. The FAA requires a warning for the pilot of an impending stall. Natural stall buffet does not provide adequate warning in all configurations for the MD-88/90. Therefore, an artificial stick shaker system and a visual and aural stall warning system were installed.

An aircraft may be stalled in any attitude (nose high, nose low, high or low angle of bank) or any airspeed (turning, accelerated stall). It is not always intuitively obvious that the aircraft is stalled.

In common with most other T-tail aircraft, the airplane is subject to a characteristic known as the “deep stall”. This term refers to an angle-of-attack range beyond the normal stall region in which the tail enters the turbulent wakes of the wing and nacelles. This causes a loss in tail effectiveness and a tendency to pitch up until the aircraft stabilizes at some very high angle-of-attack. Entry into the deep stall may not be readily apparent to the pilot since the.increase in angle-of-attack may be accompanied by increasing sink rate and flight path angle so that pitch attitudes remain low.

An aircraft stall is characterized by one or more of the following conditions:

- Stall warning
- Buffeting, which could be heavy
- Lack of pitch authority
- Lack of roll control
- Inability to arrest descent rate.

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Stall or Approach to Stall Recovery

To initiate the recovery, the angle of attack must be reduced below the wing stalling angle. Smoothly apply nose down elevator to reduce the angle of attack until the wings are unstalled (buffet or stick shaker stops). Nose down stabilizer trim may be needed if the control column does not provide the needed response.

Application of forward control column (as much as full forward may be required) and the use of some nose-down stabilizer trim should provide sufficient elevator control to produce a nose-down pitch rate. It may be difficult to know how much stabilizer trim to use, and care must be taken to avoid using too much. Pilots should not fly the aircraft using stabilizer trim, and should stop trimming nose down when they feel the g force on the aircraft lessen or the required elevator force lessen. The use of too much trim may result in the loss of control or high structural loads.

Continue the recovery by rolling in the shortest direction to wings level, as needed. If an attempt is made to roll to wings level before the wings are unstalled, the ailerons and spoilers are ineffective. Unloading the wing by maintaining continuous nose-down elevator pressure keeps the wing angle of attack low making the normal roll controls more effective. After the stall is broken, normal roll controls, up to full deflection of ailerons and spoilers, may be used to roll in the shortest direction to wings level, if needed. The use of rudder is normally not needed.

The Stall or Approach to Stall Recovery maneuver calls for the crew to advance the throttles in accordance with the maneuver.

Note: Use care during recovery from a nose low attitude after the buffet and/or stick shaker have stopped. If the pull up is too aggressive, a “secondary” stall or sustained stick shaker may result.

In extreme cases where the application of forward control column coupled with some nose-down stabilizer trim and a thrust reduction do not stop an increasing pitch rate in a nose-high situation, rolling the aircraft to a bank angle that starts the nose down may be effective. If normal roll control is ineffective, careful rudder input in the direction of the desired roll may be required. Bank angles of about 45°, up to a maximum of 60°, could be needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control.

Do not change gear or flap configuration during the recovery, unless a stall warning indication is encountered during liftoff and the flaps were inadvertently positioned up for takeoff. In this case, extend slats as directed in the Stall or Approach to Stall Recovery maneuver. Extending or retracting the flaps during the recovery at other times results in an increased altitude loss.

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If a stall warning occurs while the aircraft is in the clean configuration, after appropriate thrust and target pitch is established, the slats may be extended if below slat limit.

High Altitude Recovery

At higher altitudes, normally above 20,000 feet, the aircraft becomes increasingly thrust limited. If an approach to stall indication is experienced, nose-down elevator is required to initiate a descent. Stabilizer trim may also be required. This is because when the aircraft is thrust limited, altitude needs to be traded for airspeed. Therefore a recovery at high altitude results in a greater altitude loss than a recovery at low altitudes.

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Steep Turns

The objective of the steep turn maneuver is to familiarize the pilot with aircraft handling characteristics beyond 35° of bank, build confidence in hand flying the aircraft, and improve the instrument crosscheck. During training, 45° of bank is used for this maneuver. It is not intended that the pilot should ever be required to bank greater than 25° to 30° in any normal or non-normal condition.

Note: Stabilizer trim is not recommended during the steep turn maneuver because of increased workload during roll out.

Entry

Stabilize aircraft at 250 knots on heading and altitude. Turn off the flight directors and disconnect the autothrottles and autopilot. Use normal turn entry and slowly roll into a 45° bank. When bank angle increases above 30°, add power to maintain airspeed, and increase pitch to 3.0° to 4.0°. Maintain the bank angle, airspeed, and altitude for 180° of turn.

During Turn

Pitch and thrust control are the same as for a normal turn; however, larger pitch adjustments are required for a given altitude deviation. Varying the angle of bank while turning makes pitch control more difficult. If altitude loss becomes excessive, reduce the angle of bank as needed to regain positive pitch control.

Smooth and positive control is required. A rapid instrument scan is required to detect deviations early enough to be corrected by small adjustments.

Attitude Indicator

The attitude indicator is reliable for accurate pitch and bank information throughout the turn. Precession error does not exist because the IRS is the source of attitude information.

Vertical Speed Indicator

The VSI is not an instantaneous display. Under rapidly changing conditions, the VSI may lag actual aircraft performance by as much as four seconds.

Altimeter

Crosscheck the direction and rate of change, and make smooth minor adjustments to the pitch attitude for corrections.

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Airspeed

Airspeed changes very slowly because of small changes in thrust and drag. Anticipate thrust changes and apply them at the first indication of change on the FAST/SLOW or airspeed indicator. An increase in thrust is required as bank angle increases.

Rollout

Roll out at the same rate as used during normal turns. Normally rollout should begin 15° to 20° prior to the desired heading. A decrease in pitch is required as the bank angle is decreased to maintain constant altitude. A decrease in thrust is required to maintain constant airspeed.

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Terrain Avoidance

The Ground Proximity Warning System (GPWS) PULL UP Warning occurs when an unsafe distance or closure rate is detected with terrain below the aircraft. The EGPWS/Look-ahead terrain alerting (as installed) also provides an aural warning when an unsafe distance is detected from terrain ahead of the aircraft. If either of these occur, immediately accomplish the Terrain Avoidance maneuver.

Do not attempt to engage the autopilot and/or autothrottle until terrain clearance is assured.

Terrain Avoidance Maneuver

Ground Proximity Caution

Accomplish the following maneuver for any of these aural alerts:

- CAUTION TERRAIN
- SINK RATE
- TERRAIN
- DON'T SINK
- TOO LOW FLAPS
- TOO LOW GEAR
- TOO LOW TERRAIN
- GLIDESLOPE

Pilot Flying	Pilot Monitoring
Correct the flight path or the airplane configuration.	

The below glideslope deviation alert may be canceled or inhibited for:

- Localizer or backcourse approach
- Circling approach from an ILS
- When conditions require a deliberate approach below glideslope
- Unreliable glideslope signal.

Note: If a terrain caution occurs when flying under daylight VMC, and positive visual verification is made that no obstacle or terrain hazard exists, the alert may be regarded as cautionary and the approach may be continued.

Note: Some aural alerts repeat.

Ground Proximity Warning

Accomplish the following maneuver for any of these conditions:

- Activation of the "PULL UP", or "TERRAIN TERRAIN PULL UP" warning
- Other situations resulting in unacceptable flight toward terrain.

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Pilot Flying	Pilot Monitoring
• Disconnect autopilot. • Disconnect autothrottle(s). • Aggressively apply maximum* thrust. • Simultaneously roll wings level and rotate to an initial pitch attitude of 20°. • Retract speedbrakes. • If terrain remains a threat, continue rotation up to the pitch limit indicator or stick shaker or initial buffet.	• Assure maximum* thrust. • Verify all required actions have been completed and call out any omissions.
• Do not change gear or flap configuration until terrain separation is assured. • Monitor radio altimeter for sustained or increasing terrain separation. • When clear of the terrain, slowly decrease pitch attitude and accelerate.	• Monitor vertical speed and altitude (radio altitude for terrain clearance and barometric altitude for a minimum safe altitude). • Call out any trend toward terrain contact.

Note: Immediately rotate the aircraft at a rate of 3° per second. Aft control column force increases as the airspeed decreases. In all cases, the pitch attitude that results in intermittent stick shaker or initial buffet is the upper pitch attitude limit. Flight at intermittent stick shaker may be required to obtain positive terrain separation. Smooth, steady control will avoid a pitch attitude overshoot and stall.

Note: Do not use flight director commands.

* Maximum thrust can be obtained by:

(88) advancing the throttles to firewall.

(90) advancing the throttles through the ORT gate.

Note: If positive visual verification is made that no obstacle or terrain hazard exists when flying under daylight VMC conditions prior to a terrain or obstacle (as installed) warning, the alert may be regarded as cautionary and the approach may be continued.

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Traffic Alert and Collision Avoidance System

The Traffic Alert and Collision Avoidance System (TCAS) is designed to enhance crew awareness of nearby traffic and issue advisories for timely visual acquisition or appropriate vertical flight path maneuvers to avoid potential collisions. It is intended to support visual collision avoidance, application of right-of-way rules, and ATC separation.

Traffic Advisory

A Traffic Advisory (TA) occurs when nearby traffic meets system minimum separation criteria, and is indicated aurally and visually on the TCAS traffic display. A goal of the TA is to alert the pilot of the possibility of an RA. If a TA is received, immediately look for traffic using the traffic display as a guide, call out any conflicting traffic and if traffic is sighted, maneuver if needed. Maneuvers based solely on a TA may result in reduced separation and are not normally recommended.

Resolution Advisory

When TCAS determines that there is a risk for collision, a Resolution Advisory (RA) aural warning and a pitch command is generated. With the exception noted below, compliance with an RA is required even if the subject aircraft appears to be in sight and is deemed to be of no threat. There could be multiple threats and the aircraft observed may not actually be the offending traffic. Compliance with a Resolution Advisory (RA) is mandatory unless doing so imposes a greater risk.

WARNING: A DESCEND (fly down) RA issued below 1,000 feet AGL should not be followed.

The RA Maneuver

Maneuvering is required if the existing vertical speed is in the red band on the vertical speed indicator.

The RA maneuver is a pitch-only maneuver. Continue to follow the planned lateral flight path unless visual contact with the conflicting traffic requires other action. Properly executed, the RA maneuver is mild and should not require large or abrupt control movements.

Note: The flight director is not designed to provide RA guidance.

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Complying with RAs may result in brief exceedance of altitude and/or placard limits. However, even at the limits of the operating envelope, in most cases sufficient performance is available to safely maneuver the aircraft.

Note: The RA command "ADJUST VERTICAL SPEED ADJUST" always requires a reduction in vertical speed. Do not inappropriately increase vertical speed in response to this command. On later versions of TCAS, the verbal annunciation "ADJUST VERTICAL SPEED ADJUST" RA has been changed to "LEVEL OFF".

Pilot Flying	Pilot Monitoring
Both pilots visually clear the airspace in the direction of the maneuver.	
If maneuvering is required: • Disconnect the autopilot and autothrottle. • Smoothly adjust pitch (and thrust, if necessary) to satisfy the RA command. Follow the planned lateral flight path unless visual contact with the conflicting traffic requires other action. When TCAS advises "CLEAR OF CONFLICT", smoothly maneuver back to the ATC cleared altitude. Re-establish the autopilot and auto-thrust, as desired.	Notify ATC ("TCAS RA"). If necessary, coordinate with ATC for further clearance. Notify ATC "CLEAR OF CONFLICT"
Attempt visual contact. Call out any conflicting traffic. Visual acquisition of traffic may be misleading and does not guarantee separation. Comply with RA guidance until clear of conflict unless doing so imposes a greater risk.	
For a TCAS climb RA in the landing configuration and when clear of conflict, reset automation to appropriate level.	
• Autopilot as desired • Speed Command Bug set to desired speed for planned flap setting • Call for "FLAPS 15" • Call for "GEAR UP" • Accelerate, call for flap retraction on schedule • After Takeoff checklist	• Make MCP and configuration changes as requested by the PF

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Parallel Approach Exception to Resolution Advisory Compliance

Many airports operate simultaneous visual approaches to closely-spaced parallel runways. Occasionally, an RA is generated due to the close proximity of aircraft even though the aircraft are tracking to separate runways. A pilot may disregard RA guidance during an approach when all of the following conditions exist:

- Daytime
- VMC conditions
- Radar contact
- Parallel approach operations
- Cleared for the approach
- The traffic can be immediately and positively identified and separation can be maintained.

Note: After receiving an RA, selection of "TA Only" is not recommended. Maintaining TCAS RA guidance is desirable in the event of a go-around and/or secondary "intruder" aircraft.

Interaction with ATC

Pilots are authorized to deviate from their current ATC clearance to the extent necessary to comply with a TCAS RA. Except as specifically noted above, pilots are required to immediately comply with an RA, even if the RA is contrary to an ATC clearance or instruction issued prior to or during an active RA.

When an RA occurs, inform ATC "TCAS RA" as soon as practicable after responding to the RA.

When the RA is clear and "Clear of Conflict" is heard, inform ATC "Clear of conflict, returning to (assigned clearance)" or "Clear of conflict, reestablished (assigned clearance)."

Mode of Operation

The combined Resolution Advisory (RA) and Traffic Advisory (TA) switch position (RA/TA or TA/RA, depending on installation) should be initiated just before takeoff and continued until just after landing.

The Traffic Advisory (TA) Only mode inhibits the RA function and should be selected only when directed by:

- A Company Page, or
- An Non-Normal Checklist, or
- A flight plan remark.

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Other Considerations

During the RA maneuver, the aircrew should attempt to establish visual contact with the target. However, visual perception of the encounter can be misleading, particularly at night. The traffic acquired visually may not be the same traffic causing the RA.

Pilots should maintain situational awareness since TCAS may issue RAs in conflict with terrain considerations, such as during approaches into rising terrain or during an obstacle limited climb. Continue to follow the planned lateral flight path unless visual contact with the conflicting traffic requires other action. Windshear, EGPWS, and stall warnings take precedence over TCAS advisories. If stick shaker or initial buffet occurs during the maneuver, immediately accomplish the Approach to Stall Recovery procedure, this chapter. If high speed buffet occurs during the maneuver, relax pitch force as necessary to reduce buffet, but continue the maneuver.

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Upset Recovery

An upset can generally be defined as unintentionally exceeding the following conditions:

- Pitch attitude greater than 25° nose up, or
- Pitch attitude greater than 10° nose down, or
- Bank angle greater than 45°, 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 the actions may be necessary once recovery is underway. 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.

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Nose High Recovery

Pilot Flying	Pilot Monitoring
• Recognize and confirm the situation.	

• Disconnect autopilot and autothrottle.
• Apply as much as full nose down elevator.
• *Apply appropriate nose down stabilizer trim.
• Apply thrust as appropriate
• *Roll (adjust bank angle) to obtain a nose down pitch rate.
• Complete the recovery:
  • When approaching the horizon, roll to wings level
  • Check airspeed and adjust thrust
  • Establish pitch attitude.
	• Call out attitude, airspeed and altitude throughout the recovery.
	• Verify all required actions have been completed and call out any omissions.

Nose Low Recovery

Pilot Flying	Pilot Monitoring
• Recognize and confirm the situation.	

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

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General

Though flight crews in line operation rarely, if ever, encounter an upset situation, understanding how to apply aerodynamic fundamentals in such a situation helps them control the aircraft. Several techniques are available for recovering from an upset. In most situations, if a technique is effective, it is not recommended that pilots use additional techniques. Several of these techniques are discussed in the example scenarios below:

- Nose high, wings level
- Nose low, wings level
- High bank angles
- Nose high, high bank angles
- Nose low, high bank angles

Note: Higher than normal control forces may be required to control the aircraft attitude when recovering from upset situations. Be prepared to use a firm and continuous force on the control column and control wheel to complete the recovery.

Nose High, Wings Level

In a situation where the aircraft pitch attitude is unintentionally more than 25° nose high and increasing, the airspeed is decreasing rapidly. As airspeed decreases, the pilot's ability to maneuver the aircraft also decreases. If the stabilizer trim setting is nose up, as for slow-speed flight, it partially reduces the nose-down authority of the elevator. At full thrust settings and very low airspeeds, the elevator, working in opposition to the stabilizer, has limited control to reduce the pitch attitude.

In this situation the pilot should trade altitude for airspeed, and maneuver the aircraft's flight path back toward the horizon. This is accomplished by the input of up to full nose-down elevator and the use of some nose-down stabilizer trim. These actions should provide sufficient elevator control power to produce a nose-down pitch rate. It may be difficult to know how much stabilizer trim to use, and care must be taken to avoid using too much trim. Pilots should not fly the aircraft using stabilizer trim, and should stop trimming nose down when they feel the g force on the aircraft lessen or the required elevator force lessen. This use of stabilizer trim may correct an out-of-trim aircraft and solve a less-critical problem before the pilot must apply further recovery measures. Because a large nose-down pitch rate results in a condition of less than 1 g, at this point the pitch rate should be controlled by modifying control inputs to maintain between 0 g and 1 g.

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If normal pitch control inputs do not stop an increasing pitch rate, rolling the aircraft to a bank angle that starts the nose down should work. Bank angles of about 45°, up to a maximum of 60°, could be needed. Unloading the wing by maintaining continuous nose-down elevator pressure keeps the wing angle of attack as low as possible, making the normal roll controls as effective as possible. With airspeed as low as stick shaker onset, normal roll controls - up to full deflection of ailerons and spoilers - may be used. The rolling maneuver changes the pitch rate into a turning maneuver, allowing the pitch to decrease. Finally, if normal pitch control then roll control is ineffective, careful rudder input in the direction of the desired roll may be required to induce a rolling maneuver for recovery.

Only a small amount of rudder is needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control. Because of the low energy condition, pilots should exercise caution when applying rudder.

The reduced pitch attitude allows airspeed to increase, thereby improving elevator and aileron control effectiveness. After the pitch attitude and airspeed return to a desired range the pilot can reduce angle of bank with normal lateral flight controls and return the aircraft to normal flight.

Nose Low, Wings Level

In a situation where the aircraft pitch attitude is unintentionally more than 10° nose low and going lower, the airspeed is increasing rapidly. A pilot would likely reduce thrust and extend the speedbrakes. Thrust reduction causes an additional nose-down pitching moment. Speedbrake extension causes a nose-up pitching moment, an increase in drag, and a decrease in lift for the same angle of attack. At airspeeds well above VMO/MMO, the ability to command a nose-up pitch rate with elevator may be reduced because of the extreme aerodynamic loads on the elevator.

Again, it is necessary to maneuver the aircraft's flight path back toward the horizon. At moderate pitch attitudes, applying nose-up elevator, reducing thrust, and extending speedbrakes, if necessary, changes the pitch attitude to a desired range. At extremely low pitch attitudes and high airspeeds (well above VMO/MMO), nose-up elevator and nose-up trim may be required to establish a nose-up pitch rate.

High Bank Angles

A high bank angle is one beyond that necessary for normal flight. Though the bank angle for an upset has been defined as unintentionally more than 45°, it is possible to experience bank angles greater than 90°.

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Any time the aircraft is not in "zero-angle-of-bank" flight, lift created by the wings is not being fully applied against gravity, and more than 1 g is required for level flight. At bank angles greater than 67°, level flight cannot be maintained within AFM load factor limits. In high bank angle increasing airspeed situations, the primary objective is to maneuver the lift of the aircraft to directly oppose the force of gravity by rolling in the shortest direction to wings level. Applying nose-up elevator at bank angles above 60° causes no appreciable change in pitch attitude and may exceed normal structure load limits as well as the wing angle of attack for stall. The closer the lift vector is to vertical (wings level), the more effective the applied g is in recovering the aircraft.

A smooth application of up to full lateral control should provide enough roll control power to establish a very positive recovery roll rate. If full roll control application is not satisfactory, it may even be necessary to apply some rudder in the direction of the desired roll.

Only a small amount of rudder is needed. Too much rudder applied too quickly or held too long may result in loss of lateral and directional control or structural failure.

Nose High, High Bank Angles

A nose high, high angle of bank upset requires deliberate flight control inputs. A large bank angle is helpful in reducing excessively high pitch attitudes. The pilot must apply nose-down elevator and adjust the bank angle to achieve the desired rate of pitch reduction while considering energy management. Once the pitch attitude has been reduced to the desired level, it is necessary only to reduce the bank angle, ensure that sufficient airspeed has been achieved, and return the aircraft to level flight.

Nose Low, High Bank Angles

The nose low, high angle of bank upset requires prompt action by the pilot as altitude is rapidly being exchanged for airspeed. Even if the aircraft is at a high enough altitude that ground impact is not an immediate concern, airspeed can rapidly increase beyond aircraft design limits. Simultaneous application of roll and adjustment of thrust may be necessary. It may be necessary to apply nose-down elevator to limit the amount of lift, which will be acting toward the ground if the bank angle exceeds 90°. This also reduces wing angle of attack to improve roll capability. Full aileron and spoiler input should be used if necessary to smoothly establish a recovery roll rate toward the nearest horizon. It is important to not increase g force or use nose-up elevator or stabilizer until approaching wings level. The pilot should also extend the speedbrakes as needed.

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Upset Recovery Techniques

It is possible to consolidate and incorporate recovery techniques into two basic scenarios, nose high and nose low, and to acknowledge the potential for high bank angles in each scenario described above. Other crew actions such as recognizing the upset, reducing automation, and completing the recovery are included in these techniques. The recommended techniques provide a logical progression for recovering an aircraft.

If an upset situation is recognized, immediately accomplish the Upset Recovery maneuver.

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Windshear

General

Windshear is a change of wind speed and/or direction over a short distance along the flight path.

Improper or ineffective vertical flight path control has been one of the primary factors in many cases of flight into terrain. Low-altitude windshear encounters are especially significant because windshear can place the crew in a situation which requires the maximum performance capability of the aircraft. Windshear encounters near the ground are the most threatening because there is very little time or altitude to respond to and recover from an encounter.

Avoidance

The flight crew should search for any clues to the presence of windshear along the intended flight path. Presence of windshear may be indicated by:

- Thunderstorm activity
- Virga (rain that evaporates before reaching the ground)
- Pilot reports
- Low level windshear alerting system (LLWAS) warnings.

Stay clear of thunderstorm cells and heavy precipitation and areas of known windshear. If the presence of windshear is confirmed, delay takeoff or do not continue an approach.

Precautions

If windshear is suspected, be alert to any of the danger signals and be prepared for the possibility of an inadvertent encounter. The following precautionary actions are recommended:

Takeoff

- Use highest WDR-depicted takeoff thrust and flap settings.
- Use the longest suitable runway provided it is clear of areas of known windshear.
- Be alert for any airspeed fluctuations during takeoff and initial climb. Such fluctuations may be the first indication of windshear.
- Know the all–engine initial climb pitch attitude. Rotate at the normal rate to this attitude for all non–engine failure takeoffs. Minimize reductions from the initial climb pitch attitude until terrain and obstruction clearance is assured, unless stick shaker activates. Refer to chapter 3, Gusty Wind and Strong Crosswind Conditions for additional guidance.

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- Crew coordination and awareness are very important. Develop an awareness of normal values of airspeed, attitude, vertical speed, and airspeed build–up. Closely monitor vertical flight path instruments such as vertical speed and altimeters. The PM should be especially aware of vertical flight path instruments and call out any deviations from normal.
- Should airspeed fall below the trim airspeed, unusual control column forces may be required to maintain the desired pitch attitude. Stick shaker must be respected at all times.

Approach and Landing

- Select the minimum landing flap position consistent with field length.
- Establish a stabilized approach no lower than 1,000 feet above the airport to improve windshear recognition capability.
- Use the most suitable runway that avoids the areas of suspected windshear and is compatible with crosswind or tailwind. limitations. Use ILS G/S, G/P, or VASI/PAPI indications to detect flight path deviations and help with timely detection of windshear.
- Add an appropriate airspeed correction (correction applied in the same manner as gust), up to a maximum of 20 knots.
- Avoid large thrust reductions or trim changes in response to sudden airspeed increases as these may be followed by airspeed decreases.
- Crosscheck F/D commands using vertical flight path instruments
- Crew coordination and awareness are very important, particularly at night or in marginal weather conditions. Closely monitor the vertical flight path instruments such as vertical speed, altimeters, and glideslope displacement. The pilot monitoring should call out any deviations from normal. Use of autopilot and autothrottle for the approach may provide more monitoring and recognition time.

Recovery

Accomplish the windshear escape maneuver.

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Aircraft Performance in Windshear

Knowledge of how windshear affects aircraft performance can be essential to the successful application of the proper vertical flight path control techniques during a windshear encounter.

The wind component is mostly horizontal at altitudes below 500 feet. Horizontal windshear may improve or degrade vertical flight path performance. Windshear that improves performance is first indicated in the flight deck by an increasing airspeed. This type of windshear may be a precursor of a shear that decreases airspeed and degrades vertical flight path performance.

Airspeed decreases if the tailwind increases, or headwind decreases, faster than the aircraft is accelerating. As the airspeed decreases, the aircraft normally tends to pitch down to maintain or regain the in-trim speed. The magnitude of pitch change is a function of the encountered airspeed change. If the pilot attempts to regain lost airspeed by lowering the nose, the combination of decreasing airspeed and decreasing pitch attitude produces a high rate of descent. Unless this is countered by the pilot, a critical flight path control situation may develop very rapidly. As little as 5 seconds may be available to recognize and react to a degrading vertical flight path.

In critical low altitude situations, trade airspeed for altitude, if possible. An increase in pitch attitude, even though the airspeed may be decreasing, increases the lifting force and improves the flight path angle. Proper pitch control, combined with maximum available thrust, utilizes the total aircraft performance capability.

The crew must be aware of the normal values of airspeed, altitude, rate of climb, pitch attitude, and control column forces. Unusual control column force may be required to maintain or increase pitch attitude when airspeed is below the in-trim speed. If significant changes in airspeed occur and unusual control forces are required, the crew should be alerted to a possible windshear encounter and be prepared to take action.

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Windshear Encounter Recognition

Note: The following are indications the airplane is encountering a windshear:

- Amber windshear caution
- Windshear Immediate-Alert Warning (two-tone siren followed by "WINDSHEAR, WINDSHEAR, WINDSHEAR")
- Unacceptable flight path deviations.

  Note: Unacceptable flight path deviations are recognized as uncontrolled changes from normal steady state flight conditions below 1,000 feet AGL, in excess of any of the following:
  - 15 knots indicated airspeed
  - 500 fpm vertical speed
  - 5° pitch attitude
  - 1 dot displacement from the glideslope
  - Unusual throttle position for a significant period of time.

Windshear Escape Maneuver

Pilot Flying	Pilot Monitoring
• Disconnect autopilot. • Push either TO/GA. • Set TO/GA power. If ground contact is a factor, aggressively apply maximum* thrust. • Disconnect autothrottle(s). • Simultaneously roll wings level and rotate toward an initial pitch attitude of 15°. • Retract speedbrakes. • Follow flight director guidance (if available)	• Assure TO/GA or maximum* thrust. • Verify all required actions have been completed and call out any omissions. • Advise when windshear guidance is activated.
• Do not change flap or gear configuration until windshear is no longer a factor. • Monitor vertical speed and altitude. • Do not attempt to regain lost airspeed until windshear is no longer a factor.	• Monitor vertical speed and altitude. • Call out any trend toward terrain contact, descending flight path, or significant airspeed changes.

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Note: Aft control column force increases as the airspeed decreases. In all cases, the pitch attitude that results in intermittent stick shaker or initial buffet is the upper pitch attitude limit. Flight at intermittent stick shaker may be required to obtain a positive terrain separation. Smooth, steady control will avoid a pitch attitude overshoot and stall.

Note: (88) *Maximum thrust can be obtained by advancing the throttles to firewall. If terrain contact is imminent, advance throttles to firewall.

Note: (90) *Maximum thrust can be obtained by advancing the throttles through ORT Gate. If terrain contact is imminent, advance throttles through ORT Gate.

Windshear During Takeoff Roll

Prior to V1

Note: Predictive windshear caution alerts are inhibited between 80 knots and 400 feet RA.

(88)
Predictive windshear caution alert (“MONITOR RADAR DISPLAY” aural)

- Reject takeoff.

(88)
Predictive windshear warning alert (“WINDSHEAR AHEAD, WINDSHEAR AHEAD” aural)

- Reject takeoff.

At or Near V1

If windshear is encountered prior to V1, there may not be sufficient runway remaining to stop if an RTO is initiated at V1. If the decision is made to continue the takeoff, apply maximum thrust. At VR, rotate at a normal rate toward a 15° pitch attitude. Once airborne, perform the Windshear Escape Maneuver.

If windshear is encountered near the normal rotation speed and airspeed suddenly decreases, there may not be sufficient runway left to accelerate back to normal takeoff speed. If there is insufficient runway left to stop, ensure maximum thrust, initiate a normal rotation towards 15° at least 2,000 feet before the end of the runway even if airspeed is low. Higher than normal attitudes may be required to lift off in the remaining runway. Ensure maximum thrust is set. Once airborne, perform the Windshear Escape Maneuver.

Note: Reactive windshear indications are inhibited until nose strut extension.

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Windshear In Flight

After Takeoff

(88)
Predictive windshear caution alert (“MONITOR RADAR DISPLAY” aural)

- Maneuver as required to avoid the windshear.

(88)
Predictive windshear warning alert (“WINDSHEAR AHEAD, WINDSHEAR AHEAD” aural)

- Maneuver as required to avoid the windshear.

Windshear encounter

- Perform the Windshear Escape Maneuver.

On Approach

(88)
Predictive windshear caution alert (“MONITOR RADAR DISPLAY” aural)

- Perform a normal go-around.
- Maneuver as required to avoid the windshear.

(88)
Predictive windshear warning alert (“GO-AROUND, WINDSHEAR AHEAD” aural)

- Perform a normal go-around.
- Maneuver as required to avoid the windshear.

Windshear encounter

- Perform the Windshear Escape Maneuver.

Post Windshear Considerations

Recover from the Windshear Escape Maneuver when windshear is no longer a factor and terrain clearance is assured, then:

- Set thrust and pitch for phase of flight
- Establish aircraft configuration for phase of flight
- Reestablish automation
- Make a Windshear PIREP to ATC
- Complete the normal checklist (After Takeoff).

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Non-Normal Operations — Chapter 8
Table of Contents — Section TOC

Non-Normal Situation Guidelines 8.1
Troubleshooting 8.2
Approach and Landing 8.2
Landing at the Nearest Suitable Airport 8.4

Ditching 8.5
Send Distress Signals 8.5
Coast Guard Ditching Recommendations 8.5
Advise Crew and Passengers 8.5
Fuel Burn-Off 8.6
Passenger Cabin Preparation 8.6
Ditching Final 8.6
Initiate Evacuation 8.6

Electrical 8.7
Approach and Landing on Emergency Power 8.7

Engines, APU 8.9
Engine Failure versus Engine Fire After Takeoff 8.9
Engine Tailpipe Fire 8.9
Loss of Engine Thrust Control 8.10
Two Engine Flameout 8.10
High Engine Vibration 8.11
Recommended Technique for an In-Flight Engine Shutdown . . . 8.11
Bird Strikes 8.12
EGT Exceedance During Takeoff 8.13

Evacuation 8.14
Method of Evacuation 8.14
Discharging Fire Bottles during an Evacuation 8.15

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Emergency Landing Preparation 8.15

Flight Crew Duties Summary For Emergency Landing/ Ditching Evacuation. 8.15

Flight Controls. 8.17

Leading Edge or Trailing Edge Device Malfunctions 8.17

Jammed or Restricted Flight Controls 8.19

Stabilizer Inoperative. 8.21

Runaway Stabilizer 8.22

Flight Instruments, Displays 8.22

Airspeed Unreliable 8.22

Fuel. 8.24

Fuel Balance 8.24

Fuel Leak 8.25

Low Fuel 8.25

Hydraulics 8.25

Hydraulic System(s) Inoperative - Landing. 8.26

Landing Gear. 8.26

Braking with Antiskid Inoperative 8.26

Tire Failure during or after Takeoff. 8.26

Landing on a Flat Tire 8.27

A Partial or Gear Up Landing 8.27

Overspeed 8.30

Smoke/Fumes Principles. 8.31

Known Source 8.31

Unknown Source 8.31

Smoke/Fumes Priorities 8.32

General. 8.32

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Priorities 8.32

Warning Systems 8.33

Windows 8.33

Window Damage 8.33

Flight with the Side Window(s) Open 8.33

Situations Beyond the Scope of Non-Normal Checklists 8.34

Basic Aerodynamics and Systems Knowledge 8.34

Flight Path Control 8.36

Checklists with Memory Steps 8.37

Communications 8.37

Damage Assessment and Aircraft Handling Evaluation 8.37

Landing Airport 8.39

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Non-Normal Situation Guidelines

When a non-normal situation occurs, the following guidelines apply:

- NON-NORMAL RECOGNITION: The crewmember recognizing the malfunction calls it out clearly and precisely.
- MAINTAIN AIRCRAFT CONTROL: It is mandatory that the Pilot Flying (PF) fly the aircraft while the Pilot Monitoring (PM) accomplishes the NNC. Maximum use of the autoflight system is recommended to reduce crew workload.
- ANALYZE THE SITUATION: NNCs should be accomplished only after the malfunctioning system has been positively identified. Review all caution and warning lights to positively identify the malfunctioning system(s).

  Note: Pilots should don oxygen masks and establish crew communications any time oxygen deprivation or air contamination is suspected, even though an associated warning has not occurred.

- TAKE THE PROPER ACTION: Although some in-flight non-normal situations require immediate corrective action, difficulties can be compounded by the rate the PF issues commands and the speed of execution by the PM. Commands must be clear and concise, allowing time for acknowledgment of each command prior to issuing further commands. The PF must exercise positive control by allowing time for acknowledgment and execution. The other crewmembers must be certain their reports to the PF are clear and concise, neither exaggerating nor understating the nature of the non-normal situation. This eliminates confusion and ensures efficient, effective, and expeditious handling of the non-normal situation.
- EVALUATE THE NEED TO LAND: If the NNC directs the crew to plan to land at the nearest suitable airport, or if the situation is so identified in the QRH, NNCI.1, diversion to the nearest airport where a safe landing can be accomplished is required. If the NNC or the Non-Normal Checklist Instructions do not direct landing at the nearest suitable airport, the pilot must determine if continued flight to destination may compromise safety.

Refer to chapter 9, Human Factors.

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Troubleshooting

Troubleshooting can be defined as:

- taking steps beyond a published NNC in an effort to improve or correct a non-normal condition,
- initiating an annunciated checklist without a light, alert, or other indication to improve or correct a perceived non-normal condition, and
- initiating diagnostic actions.

Examples of troubleshooting are:

- attempting to reset a system by cycling a system control or circuit breaker when not directed by the NNC,
- using maintenance-level information to diagnose or take action, and
- using switches or controls intended only for maintenance.

Troubleshooting beyond checklist directed actions is rarely helpful and has caused further loss of system function or failure. In some cases, accidents and incidents have resulted. The crew should consider additional actions beyond the checklist only when completion of the published checklist steps clearly results in an unacceptable situation. In the case of aircraft controllability problems when a safe landing is considered unlikely, aircraft handling evaluations with gear, flaps, or speedbrakes extended may be appropriate. In the case of jammed flight controls, do not attempt troubleshooting beyond the actions directed in the NNC unless the aircraft cannot be safely landed with the existing condition. Always comply with NNC actions to the extent possible.

Note: Flight crew entry into an electronics compartment in flight is not recommended.

Crew distraction, caused by preoccupation with troubleshooting, has been a key factor in several fuel starvation and CFIT accidents. Complete the NNC as published whenever possible, in particular for flight control malfunctions that are addressed by an NNC. Guidance for situations beyond the scope of the non-normal checklist is provided later in this chapter.

Approach and Landing

When a non-normal situation occurs, a rushed approach can often complicate the situation. Unless circumstances require an immediate landing, complete all corrective actions before beginning the final approach.

For some non-normal situations, the possibility of higher airspeed on approach, longer landing distance, a different flare profile, or a different landing technique should be considered.

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Plan an extended straight-in approach with time allocated for the completion of any lengthy NNC steps such as the use of alternate flap or landing gear extension systems. Arm autobrakes and speedbrakes unless precluded by the NNC.

Note: The use of autobrakes is recommended because maximum autobraking may be more effective than maximum manual braking due to timely application upon touchdown and symmetrical braking. However, the ODM, Abnormal section provides abnormal configuration landing distance data based on the use of maximum manual braking. When used properly, maximum manual braking provides the shortest stopping distance. If stopping distance is critical, consider using max autobrakes for the touchdown and quickly transitioning to max manual brakes to stop the aircraft.

Fly a normal glide path and attempt to land in the normal touchdown zone. After landing, use available deceleration measures to bring the aircraft to a complete stop on the runway. The captain must determine if an immediate evacuation should be accomplished or if the aircraft can be safely taxied off the runway.

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Landing at the Nearest Suitable Airport

“Plan to land at the nearest suitable airport” is a phrase used in the QRH. This section explains the basis for that statement and how it is applied.

In a non-normal situation, the pilot in command, having the authority and responsibility for operation and safety of the flight, must make the decision to continue the flight as planned or divert. In an emergency situation, this authority may include necessary deviations from any regulation to meet the emergency. In all cases, the pilot in command is expected to take a safe course of action.

The QRH assists flight crews in the decision making process by indicating those situations where “landing at the nearest suitable airport” is required. These situations are described in the Non-Normal Checklist Instructions or the individual NNC.

The regulations regarding an engine failure are specific. Most regulatory agencies specify that the pilot in command of a twin-engine aircraft that has an engine failure or engine shutdown should land at the nearest suitable airport at which a safe landing can be made.

A suitable airport must have adequate facilities and meet certain minimum weather and field conditions. If required to divert to the nearest suitable airport (twin-engine aircraft with an engine failure), the pilot should select the nearest suitable airport “in point of time” or “in terms of time.” In selecting the nearest suitable airport, the pilot in command should consider the suitability of nearby airports in terms of facilities and weather and their proximity to the aircraft position. The pilot in command may determine, based on the nature of the situation and an examination of the relevant factors, that the safest course of action is to divert to a more distant airport than the nearest airport. For example, there is not necessarily a requirement to spiral down to the airport nearest the aircraft's present position if, in the judgment of the pilot in command, it would require equal or less time to continue to another nearby airport. Refer to FOM, chapter 10.1, Engine Failure/Stall/Surge, Considerations, Suitable Airport.

For persistent smoke or a fire which cannot positively be confirmed to be completely extinguished, the safest course of action typically requires the earliest possible descent, landing, and evacuation. This may dictate landing at the nearest airport appropriate for the aircraft type, rather than at the nearest suitable airport normally used for the route segment where the incident occurs.

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Ditching

When the decision has been made to ditch, complete the Ditching NNC in the QRH.

Refer to the Flight Crew Duties Summary For Emergency Landing/Ditching Evacuation table, this chapter.

Send Distress Signals

Transmit Mayday, current position, course, speed, altitude, situation, intention, time and position of intended touchdown, and type of aircraft using existing air-to-ground frequency. Set transponder code 7700 and, if practical, determine the course to the nearest ship or landfall. Refer to Airway Manual, Jeppessen Pages, Distress and Urgency Procedures.

Coast Guard Ditching Recommendations

In a ditching situation, the captain should consider requesting a US Coast Guard Search and Rescue (SAR) aircraft to launch for intercept. Initial contact with SAR may be made on 121.5 MHz. To assist SAR aircraft, squawk 7700 unless assigned another code.

The SAR aircraft may intercept 1,000 feet below your aircraft in VFR or 1,000 feet above in IFR. Therefore, the altimeters of each aircraft must be compared prior to intercept to ensure safe vertical separation.

If ditching is unavoidable, the Coast Guard may be able to recommend a ditching heading either through the SAR aircraft or from a surface ship. If possible, ditch in the lee of an island, in a lagoon, or near a ship.

USCG and Navy vessels may be able to communicate on 121.5 MHz.

Coast Guard, Navy, and some merchant ships may have the capability of supplying homing signals, radar for intercept, flares for night ditching, and other aids. Standard low frequency homing signal is 410 kHz, giving the call sign, followed by 2 (two) 10 (ten) second dashes.

Advise Crew and Passengers

Alert the crew and the passengers to prepare for ditching. Assign life raft positions (as installed) and order all loose equipment in the aircraft secured. Put on life vests, shoulder harnesses, and seat belts. Do not inflate life vests until after exiting the aircraft.

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Fuel Burn-Off

Consider burning off fuel prior to ditching, if the situation permits. This provides greater buoyancy and a lower approach speed. However, do not reduce fuel to a critical amount, as ditching with engine thrust available improves ability to properly control touchdown.

Passenger Cabin Preparation

Confer with cabin personnel either by interphone or by having them report to the flight deck in person to ensure passenger cabin preparations for ditching are complete.

Ditching Final

Transmit final position. Select flaps 28 appropriate for the existing conditions.

Advise the cabin crew of imminent touchdown. On final approach announce ditching is imminent and advise crew and passengers to brace for landing. Maintain airspeed at VREF. Maintain 200 to 300 fpm rate of descent. Plan to touch down on the windward side and parallel to the waves or swells, if possible. To accomplish the flare and touchdown, rotate smoothly to touchdown attitude of 10° to 12°. Maintain airspeed and rate of descent with thrust.

Initiate Evacuation

After the aircraft has come to rest, proceed to assigned ditching stations and deploy slides/rafts. Evacuate as soon as possible, ensuring all passengers are out of the aircraft.

Note: Be careful not to rip or puncture the slides/rafts. Avoid drifting into or under parts of the aircraft. Remain clear of fuel-saturated water.

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Electrical

Approach and Landing on Emergency Power

The probability of a total and unrecoverable AC power failure is remote. During training, or in the unlikely event that a landing must be made on emergency power, the following guidelines should be considered:

- Plan
  - Avoid IMC
  - Land at nearest suitable airport
  - Review major items available when reduced to operating on battery only (emergency power switch ON).
- Aviate
  - Manual pressurization/manual temperature control
  - No stabilizer trim
  - No ATS
  - No autopilot
  - No ice protection (engine anti-ice may stay on if it was on at time of the failure).
- Navigate
  - Captain's VHF nav and primary flight instruments
  - No DME
  - Heading and course readout on captain's ND only (DFGC displays captain's VHF nav frequency only).
- Communicate
  - Captain's VHF and cockpit speaker
  - Flight interphone
  - PA
- Instrument Approach Capability
  - Raw data ILS
  - Raw data localizer
  - VOR
- Landing
  - Gear and slat operation is normal.
    - Refer to QRH for flap/slat configuration (no indication and mid-seal slats only).
  - Manual spoilers
  - Manual brakes, no anti-skid

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- Thrust reversers (no indication).
- Compute approach reference speed if required. Depending on where stabilizer is stuck, yoke pressure can be heavy. Speed additive is due to the elevator not being big enough to compensate for the stuck stabilizer.

Note: Refer to Vol. 1, SP.6, Emergency Power Summary of Operative Equipment.

Fly the approach on speed. Anti-skid is not available, so excess approach speed is undesirable. Do not reduce thrust until landing flare has been initiated and sink rate has been reduced. Brake with caution.

The captain may require verbal assistance with glidepath, rate of descent, and airspeed from the first officer.

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Engines, APU

Engine Failure versus Engine Fire After Takeoff

The NNC for an engine failure is normally accomplished after maneuvering speed has been established and conditions permit.

In case of an engine fire, when the aircraft is under control, the gear has been retracted, and a safe altitude has been attained (minimum 400 feet AGL) accomplish the NNC memory items. Due to asymmetric thrust considerations, the PF retards the affected throttles after the PM confirms that the PF has identified the correct engine. Reference items should be accomplished on a non-interfering basis with other normal duties after maneuvering speed has been established and conditions permit.

Engine Tailpipe Fire

Engine tailpipe fires are typically caused by engine control malfunctions that result in the ignition of pooled fuel. These fires can be damaging to the engine and have caused unplanned evacuations.

If a tailpipe fire is reported, the crew should accomplish the NNC without delay. Flight crews should consider the following when dealing with this situation:

- Motoring the engine is the primary means of extinguishing the fire.
- To prevent an inappropriate evacuation, flight attendants should be notified without significant delay.
- Communications with ramp personnel and the tower are important to determine the status of the tailpipe fire and to request fire extinguishing assistance.
- The engine fire checklist is inappropriate because the engine fire extinguishing agent is not effective against a fire inside the tailpipe.

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Loss of Engine Thrust Control

All turbo fan engines are susceptible to this malfunction whether engine control is hydro-mechanical, hydro-mechanical with supervisory electronics (e.g. PMC) or (90 only) Full Authority Digital Engine Control (FADEC). Engine response to a loss of control varies from engine to engine. Malfunctions have occurred in-flight and on the ground. The major challenge the flight crew faces when responding to this malfunction is recognizing the condition and determining which engine has malfunctioned. The Engine(s) Compressor Stall NNC is written to include this malfunction. This condition can occur during any phase of flight.

Failure of engine or fuel control system components or loss of throttle position feedback has caused loss of engine thrust control. Control loss may not be immediately evident since many engines fail to some fixed RPM or throttle condition. This fixed RPM or throttle condition may be very near the commanded throttles and therefore difficult to recognize until the flight crew attempts to change thrust. With any failure of this type, the engine manufacturer's programming or design failure may cause the engine to accelerate, go to idle thrust, maintain the current power setting, or in a few cases, shut down. In all cases, the affected engine does not respond to throttle movement or the response is abnormal.

Since recognition may be difficult, if a loss of engine control is suspected, the flight crew should continue the takeoff or remain airborne until the NNC can be accomplished. This helps with directional control and may preclude an inadvertent shutdown of the wrong engine. In some conditions, such as during low speed ground operations, immediate engine shutdown may be necessary to maintain directional control.

Two Engine Flameout

Dual engine failure is a situation that demands prompt action regardless of altitude or airspeed. Accomplish memory items and establish the appropriate airspeed to immediately attempt a windmill restart. There is a higher probability that a windmill start will succeed if the restart attempt is made as soon as possible (or immediately after recognizing an engine failure) to take advantage of high engine RPM. Use of higher airspeeds and altitudes below 30,000 feet improves the probability of a restart. Loss of thrust at higher altitudes may require descent to a lower altitude to improve windmill starting capability.

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The in-flight start envelope defines the region where windmill starts were demonstrated during certification. It should be noted that this envelope does not define the only areas where a windmill start may be successful. The Two Engine Flameout NNC is written to ensure that flight crews take advantage of the high RPM at engine failure regardless of altitude or airspeed. Initiate the memory portion of the Two Engine Flameout NNC before attempting an (88) APU start for the reasons identified above. If the windmill restart is not successful, an APU start should be initiated as soon as practical to provide electrical power.

A hung or stalled in-flight start is normally indicated by stagnant RPM and increasing EGT. During start, engines may accelerate to idle slowly but action should not be taken if RPM is increasing and EGT is not near or rapidly approaching the limit.

Note: When electrical power is restored, do not confuse the establishment of APU generator power with the establishment of engine generator power at idle RPM and advance the throttles prematurely.

High Engine Vibration

Certain engine failures, such as fan blade separation, can cause high levels of airframe vibration. Although the airframe vibration may seem severe to the flight crew, it is extremely unlikely that the vibration will damage the aircraft structure or critical systems. However, the vibration should be reduced as soon as possible by reducing airspeed and descending. As altitude and airspeed change, the aircraft may transition through various levels of vibration. In general, vibration levels decrease as airspeed decreases; however, at a given altitude vibration may temporarily increase or decrease as airspeed changes.

If vibration remains unacceptable, descending to a lower altitude (terrain permitting) allows a lower airspeed and normally lower vibration levels.Vibration will likely become imperceptible as airspeed is further reduced during approach.

Once airframe vibration has been reduced to acceptable levels, the crew must evaluate the situation and determine a new course of action based on weather, fuel remaining, and available airports.

Recommended Technique for an In-Flight Engine Shutdown

Any time an engine shutdown is needed in flight, good crew coordination is essential.

When the flight path is under complete control, the crew should proceed with a deliberate, systematic process that identifies the affected engine and ensures that the operating engine is not shut down. Do not rush through the shutdown checklist, even for a fire indication. The following technique is an example that could be used:

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When an engine shutdown is needed, the PF disconnects the A/T. The PF then verbally coordinates confirmation of the affected engine with the PM and then slowly retards the throttles of the engine that will be shut down.

Coordinate activation of the (88) fuel lever, (90) fuel switch as follows:

- PM places a hand on and verbally identifies the (88) fuel lever, (90) fuel switch for the engine that will be shut down
- PF verbally confirms that the PM has identified the correct (88) fuel lever, (90) fuel switch
- PM moves the (88) fuel lever, (90) fuel switch to cutoff.

If the NNC requires activation of the engine fire handle, coordinate as follows:

- PM places a hand on and verbally identifies the engine fire handle for the engine that is shutdown
- PF verbally confirms that the PM has identified the correct engine fire handle
- PM pulls the engine fire handle.

Bird Strikes

Experience shows that bird strikes are common in aviation. Most bird strikes occur at very low altitudes, below 500 feet AGL. This section deals with bird strikes that affect the engines.

Recent studies of engine bird strikes reveal that approximately 50% of engine bird strikes damage the engine(s). The risk of engine damage increases proportionally with the size of the bird and with increased engine thrust settings. When an engine bird strike damages the engine, the most common indications are significant vibrations due to fan blade damage and an EGT increase.

Note: After any bird strike, the engines should be inspected by maintenance.

Preventative Strategies

Airports are responsible for bird control and should provide adequate wildlife control measures. If large birds or flocks of birds are reported or observed near the runway, the crew should consider:

- Delaying the takeoff or landing when fuel permits. Advise the tower and wait for airport action before continuing
- Taking off or landing on another runway that is free of bird activity, if available.

To prevent or reduce the consequences of a bird strike, the crew should:

- Discuss bird strikes during takeoff and approach briefings when operating at airports with known or suspected bird activity
- Be extremely vigilant if birds are reported on final approach

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- If birds are expected on final approach, plan additional landing distance to account for the possibility of no thrust reverser use if a bird strike occurs.

Note: The use of weather radar to scare the birds has not been proven effective.

Crew Actions for a Bird Strike During Takeoff

If a bird strike occurs during takeoff, the decision to continue or reject the takeoff is made using the criteria found in chapter 3, Rejected Takeoff Decision.

If a bird strike occurs above 80 knots and prior to V1, and there is no immediate evidence of engine failure (e.g. failure, fire, power loss, or surge/stall), the preferred option is to continue with the takeoff followed by an immediate return, if required.

Crew Actions for a Bird Strike During Approach or Landing

If the landing is assured, continuing the approach to landing is the preferred option. If more birds are encountered, fly through the bird flock and land. Maintain as low a thrust setting as possible.

If engine ingestion is suspected, limit reverse thrust on landing to the amount needed to stop on the runway. Reverse thrust may increase engine damage, especially when engine vibration or high EGT is indicated.

EGT Exceedance During Takeoff

If an engine exceedance occurs after thrust is set and the decision is made to continue the takeoff, do not retard the throttles in an attempt to control the exceedance. Retarding the throttles after thrust is set invalidates takeoff performance. When the PF judges that altitude (minimum 400 feet AGL) and airspeed are acceptable, the throttles should be retarded until the exceedance is within limits and the appropriate NNC accomplished. Enter the exceedance in the aircraft logbook.

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Evacuation

If an evacuation is planned and time permits, a thorough briefing and preparation of the crew and passengers improves the chances of a successful evacuation. Flight deck preparations should include a review of pertinent checklists and any other actions to be accomplished. Appropriate use of autobrakes should be discussed. If evacuating due to fire in windy conditions, consider positioning the aircraft so the fire is on the downwind side.

Notify cabin crew of possible adverse conditions at the affected exits. The availability of various exits may differ for each situation. Crewmembers must make the decision as to which exits are usable for the circumstances.

For unplanned evacuations, the captain needs to analyze the situation carefully before initiating an evacuation order. Quick actions in a calm and methodical manner improve the chances of a successful evacuation.

Refer to the Flight Crew Duties Summary For Emergency Landing/Ditching Evacuation table, this chapter.

Method of Evacuation

When there is a need to evacuate passengers and crew, the captain has to choose between commanding an emergency evacuation using the emergency escape slides or less urgent means such as deplaning using stairs, jetways, or other means. All available sources of information should be used to determine the safest course of action including reports from the cabin crew, other aircraft, and air traffic control. The captain must then determine the best means of evacuation by carefully considering all factors. These include, but are not limited to:

- The urgency of the situation, including the possibility of significant injury or loss of life if a significant delay occurs
- The type of threat to the aircraft, including structural damage, fire, reported bomb on board, etc.
- The possibility of fire spreading rapidly from spilled fuel or other flammable materials
- The extent of damage to the aircraft
- The possibility of passenger injury during an emergency evacuation using the escape slides.

If in doubt, the crew should consider an emergency evacuation using the escape slides.

If there is a need to deplane passengers, but circumstances are not urgent and the captain determines that the Evacuation NNC is not needed, the normal shutdown procedure should be completed before deplaning the passengers.

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Discharging Fire Bottles during an Evacuation

The evacuation NNC specifies discharge of the engine or APU fire bottles if an engine or APU fire warning light is illuminated. However, evacuation situations can present possibilities regarding the potential for fire that are beyond the scope of the NNC and may not activate an engine or APU fire warning. The crew should consider the following when deciding whether to discharge one or more fire bottles into the engines and/or APU:

- If an engine fire warning light is not illuminated, but a fire indication exists or a fire is reported in or near an engine, discharge both available fire bottles into the affected engine.
- If the APU fire warning light is not illuminated, but a fire indication exists or a fire is reported in or near the APU, discharge the APU bottle(s).
- The discharged halon agent is designed to extinguish a fire and has very little or no fire prevention capability in the engine nacelles. Halon dissipates quickly into the atmosphere.
- There is no reason to discharge the engine or APU fire bottles for evacuations not involving fire indications existing or reported in or near an engine or APU, e.g., cargo fire, security or bomb threat, etc.

Emergency Landing Preparation

Refer to the QRH, NNC, Emergency Landing Considerations.

Refer to the FOM, chapter 10.1, Emergency Landing Preparation.

Flight Crew Duties Summary For Emergency Landing/ Ditching Evacuation

The following flight crew duties summary is designed to assist the crew members in preparing the aircraft's occupants for emergency landing and evacuation. Time is essential in preparing passengers for the evacuation (especially non-ambulatory). Flight attendants should be advised of the problem(s) as soon as flight safety is in doubt. Specific flight attendant duties are outlined in the In-Flight Service On-Board Manual. Additionally, the flight attendants should be informed of any conditions such as high winds, irregular ground condition, sea state, structural damage, and/or fire that affect or alter status of the escape slides/raft deployment.

After evaluating all factors, consideration may be given to securing the flight deck door open in preparation for an emergency landing. This could enhance flight deck evacuation; however, this increases the importance of securing all items aft of the flight deck.

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Pre Landing/Ditching	
Captain	**First Officer**
• Advise crew to prepare for emergency landing (or ditching) and order distress message sent. • Set course for most logical point of landing under existing circumstances. • Order cockpit emergency preparation as conditions dictate. • Fasten seat belt and shoulder harness. • Signal cabin crew/passengers when touchdown is imminent, using PA system if operative. • If ditching: don life vest.	• Send distress message (MAY DAY), giving aircraft identification, type, position, heading, airspeed, altitude, fuel remaining in hours and minutes, nature of distress, intentions, and assistance desired. • Assist in cockpit emergency preparations as directed by the Captain and as conditions dictate. • Fasten seat belt and shoulder harness. • If ditching: don life vest.

Post Landing/Ditching	
Captain	**First Officer**
• Order evacuation. • Proceed to forward cabin area and assist in evacuating passengers as conditions dictate. • After ensuring that all passengers are off the aircraft or all possible assistance has been given, exit from the rear of the aircraft if able. • When all possible assistance has been given, leave the aircraft and assume command outside. • After exiting, assemble pax's/rafts away from the aircraft.	• Remove and carry ELT from behind first officers seat. • Assist in opening forward cabin door and exit the aircraft. • Assist in the evacuation of passengers from the exterior of the aircraft as conditions dictate. • Assist in assembling passengers/rafts away from the aircraft. Board raft.

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Flight Controls

Leading Edge or Trailing Edge Device Malfunctions

Leading edge or trailing edge device malfunctions can occur during extension or retraction. This section discusses all flaps up and partial or asymmetrical leading/trailing edge device malfunctions for landings.

No Flaps/No Slat Landing

The probability of both leading and trailing edge devices failing to extend is remote. If a flaps up landing situation were to be encountered in service, the pilot should consider the following techniques. Training to this condition should be limited to the flight simulator.

Fly a wide pattern to allow for the increased turning radius required for the higher maneuver speed. Establish final approximately 10-15 nm from the runway. This allows time to extend the gear and decelerate to the target speed while in level flight and complete all required checklists. Maintain no slower than flaps-up maneuver speed until established on final. Maneuver with normal bank angles until on final.

Final Approach

Use an ILS glide slope if available. Do not reduce the airspeed to the final approach speed until aligned with the final approach. Before intercepting the descent profile, decrease airspeed to the FLAPS 0, SLATS RET 1.25 V speed and maintain this speed until the landing is assured.Limit bank angle to 15°. The approach/landing speed does not provide normal bank angle maneuvering capability.

The normal rate of descent on final is approximately 900 fpm due to the higher ground speed. Anticipate possible “SINK RATE” GPWS warning due to the high rate of descent. Final approach body attitude is approximately 4° - 5° aircraft nose up. Do not make a flat approach (shallow glide path angle) or aim for the threshold of the runway. Use a normal aim point approximately 1,000 feet down the runway.

Note: Use of the autopilot during approach phase is acceptable.

Speedbrakes are not recommended for airspeed reduction at radio altitude less than 1,000 feet. If landing is anticipated beyond the normal touch down zone, go around.

Use an ILS glidepath if available.

Disconnect autothrottles. Autothrottles will not allow aircraft to slow to final approach speed. Prior to intercepting descent profile, decrease airspeed to final approach speed and maintain this speed until landing is assured.

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Engines will be at a low speed due to no flap extension. When engines are near idle RPM, time required for engines to accelerate is longer than normal.

Landing

Fly the aircraft onto the runway for a positive touchdown to avoid float. Normal landing flare may cause aircraft to balloon. Floating just above the runway surface to deplete additional speed wastes available runway and increases the possibility of a tail strike. Do not risk touchdown beyond the normal touchdown zone in an effort to achieve a smooth landing.

Slight forward pressure on the control column may be needed to achieve touchdown at the desired point and to lower the nose wheels to the runway. After lowering the nose wheels to the runway, hold light forward control column pressure and expeditiously accomplish the landing roll procedure. Full reverse thrust is needed for a longer period of time.

Use normal reverse thrust procedures (reverse thrust is more effective at high speeds). Autobrakes are inoperative. Smoothly apply manual brakes to full pedal deflection. Be alert for excessive brake temperatures after landing.

Asymmetrical or No Slat - Landing

If a slat asymmetry/no slat malfunction occurs, the adjusted VREF provides 15° bank angle maneuvering capability.

Do not hold the aircraft off during landing flare. Floating just above the runway surface to deplete the additional threshold speed wastes available runway and increases the possibility of a tail strike.

Note: If the gear is retracted during a go-around and flap position is greater than 26°, a landing gear configuration warning occurs.

Asymmetrical Trailing Edge Flaps - Landing

If flaps fail to extend or retract to selected position, consider burning off fuel to reduce landing weight and lower approach speed. Check actual landing distance in the ODM abnormal section.

Fly accurate airspeeds in the landing pattern. At lesser flap settings, excess airspeed is difficult to dissipate, especially when descending on final approach. Pitch attitude and rate of descent on final is higher than for a normal landing. During flare, airspeed does not bleed off as rapidly as normal.

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Fly the aircraft onto the runway at the recommended touchdown point. Flare only enough to achieve an acceptable reduction in the rate of descent. Do not allow the aircraft to float. Floating just above the runway surface to deplete additional speed wastes available runway and increases the possibility of a tail strike. Do not risk touchdown beyond the normal touchdown zone in an effort to achieve a smooth landing. Autobrakes are inoperative if flaps are less than 26°.

Note: If the gear is retracted during a go-around and flap position is greater than 26°, a landing gear configuration warning occurs.

Jammed or Restricted Flight Controls

Although rare, jamming of the flight control system has occurred on commercial aircraft. A jammed flight control can result from ice accumulation due to water leaks onto cables or components, dirt accumulation, component failure such as cable break or worn parts, improper lubrication, or foreign objects.

A flight control jam may be difficult to recognize, especially in a properly trimmed aircraft. A jam in the pitch axis may be more difficult to recognize than a jam in other axes. In the case of the elevator, the jammed control can be masked by trim. Some indications of a jam are:

- Unexplained autopilot disengagement
- Autopilot that cannot be engaged
- Undershoot or overshoot of an altitude during autopilot level-off
- Higher than normal control forces required during speed or configuration changes.

If any jammed flight control condition exists, both pilots should apply force to try to either clear the jam or activate the override feature. There should be no concern about damaging the flight control mechanism by applying too much force to either clear a jammed flight control or activate an override feature. Maximum force may result in some flight control surface movement with a jammed flight control. If the jam clears, both pilot's flight controls are available.

Note: If a control is jammed due to ice accumulation, the jam may clear when moving to a warmer temperature.

Note: There are override features for the control wheel.

90

Note: There are override features for the control wheel and the control column. The control column disconnect mechanism requires 125 pounds of breakout force to separate the columns and allows for the use of a single unjammed elevator. Large asymmetric elevator inputs can create substantial roll moments in the T-Tail. In order to minimize structural risk, control inputs should not be large, nor abrupt. Refer to the "ELEVATOR SPLIT" non-normal checklist in the QRH for airspeed limitations.

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If the jam does not clear, activation of an override feature allows a flight control surface to be moved independent of the jammed control. Applying force to the non-jammed flight control activates the override feature. When enough force is applied, the jammed control is overridden allowing the non-jammed control to operate. To identify the non-jammed flight control, apply force to each flight control individually. The flight control that results in the greatest aircraft control is the non-jammed control.

Note: The pilot of the non-jammed control should be the pilot flying for the remainder of the flight.

The non-jammed control requires a normal force, plus an additional override force to move the flight control surface. For example, if a force of 10 lbs (4 kgs) is normally needed to move the surface, and 50 lbs (23 kgs) of force is needed to activate the override, a total force of 60 lbs (27 kgs) is needed to move the control surface while in override. Response is slower than normal with a jammed flight control; however, sufficient response is available for aircraft control and landing.

For those controls without override features, limited flight control surface deflection occurs when considerable force is applied to the flight control. This response is due to cable stretch and structural bending. This response may be sufficient for aircraft control and landing.

Trim Inputs

If a jammed flight control condition exists, use manual inputs from other control surfaces to counter pressures and maintain a neutral flight control condition. The following table provides trim inputs that may be used to counter jammed flight control conditions.

Jammed Control Surface	Manual Trim Inputs
Elevator	Stabilizer
Aileron	Rudder
Rudder	Aileron

Note: Asymmetric engine thrust may aid roll and directional control.

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Approach and Landing

Attempt to select a runway with minimum crosswind. Complete approach preparations early. Recheck flight control surface operation prior to landing to determine if the malfunction still exists. Do not make abrupt thrust, speedbrake, or configuration changes. Make small bank angle changes. On final approach, do not reduce thrust to idle until after touchdown. Asymmetrical braking and asymmetrical thrust reverser deployment may aid directional control on the runway.

Note: In the event of an elevator jam, as the aircraft comes into ground effect the aircraft can be expected to experience loss of download effect on the horizontal stabilizer. This will result in a tendency for the nose to drop. This can be countered with small thrust, or ANU stab trim inputs. Avoid allowing the nose-down movement to develop. Once the nose starts to drop, as the runway is approached, it may not be possible to arrest that movement, and a landing on the nose gear may result. If the attempt to stave off that nose-down movement results in too much pitch up, suggesting an unstable situation, or the likelihood of landing long, the best solution may be to continue the go-around, and use knowledge gained from that approach, to try again. Insufficient power addition, or too little trim input during ground effect penetration is more critical than too much. If the landing attempt appears to be uncertain, trying to correct it close to the runway is not advisable. Normal throttle retardation to idle for the flare maneuver is not advised, as rapid thrust reduction will result in the nose dropping, risking a nosewheel-first landing.

Go-Around Procedure

To execute a go-around with a jammed elevator, smoothly advance throttles while maintaining pitch control with stabilizer and any available elevator. If a go-around is required, the go-around procedure is handled in the same manner as a normal go-around.

Stabilizer Inoperative

A stabilizer may jam as a result of dirt or ice on the jackscrew or due to mechanical failure. Regardless of the stabilizer position, the pilot still has sufficient elevator control to land the aircraft. However, elevator authority is limited. The QRH specifies an adjusted approach speed and landing configuration that ensures adequate elevator control is available for the remainder of the flight. Use normal piloting techniques for landing.

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Runaway Stabilizer

Hold the control column firmly to maintain the desired pitch attitude. If uncommanded trim motion continues, the stabilizer trim commands are interrupted when the control wheel trim switches are displaced in the opposite direction.

Flight Instruments, Displays

Airspeed Unreliable

Increased reliance on automation has de-emphasized the practice of setting known pitch attitudes and thrust settings. However, should an airspeed unreliable incident occur, the flight crew should be familiar with the approximate pitch attitude and thrust setting for each phase of flight. This familiarity can be gained by noting the pitch attitude and thrust setting occasionally during normal flight. Any significant change in body attitude from the attitude normally required to maintain a particular airspeed or Mach number should alert the flight crew to a potential airspeed problem.

If abnormal airspeed is recognized, set the gear up pitch attitude and thrust settings indicated in the Airspeed Unreliable NNC. When aircraft control is established, accomplish the Airspeed Unreliable NNC. Refer to the Operation Without Airspeed Indications tables in the ODM for the correct attitude, thrust settings, and V/S for actual aircraft gross weight and altitude.

Unreliable airspeed indications can result from blocking or freezing of the pitot/static system or a severely damaged or missing radome. When the ram air inlet to the pitot head is blocked, pressure in the probe is released through the drain holes and the airspeed slowly drops to zero. If the ram air inlet and the probe drain holes are both blocked, pressure trapped within the system reacts unpredictably. The pressure may increase through expansion, decrease through contraction, or remain constant. In all cases, the airspeed indications would be abnormal. This could mean increasing indicated airspeed in climb, decreasing indicated airspeed in descent, or unpredictable indicated airspeed in cruise.

If the flight crew is aware of the problem, flight without the benefit of valid airspeed information can be safely conducted and should present little difficulty. Early recognition of erroneous airspeed indications requires familiarity with the interrelationship of attitude, thrust setting, and airspeed. A delay in recognition could result in loss of aircraft control.

Ground speed information is available from the FMS and on the instrument displays. These indications can be used as a crosscheck. Many air traffic control radars can also measure ground speed.

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Descent

Idle thrust descents to 10,000 feet can be made by flying body attitude and checking rate of descent in the ODM tables. At 2,000 feet above the selected level off altitude, reduce rate of descent to 1,000 FPM. On reaching the selected altitude, establish attitude and thrust for the aircraft configuration. If possible, allow the aircraft to stabilize before changing configuration and altitude.

Approach

If available, accomplish an ILS approach. Establish landing configuration early on final approach. At glide slope intercept or beginning of descent, set thrust and attitude per the ODM tables and control the rate of descent with thrust.

Landing

Control the final approach so as to touch down approximately 1,000 feet to 1,500 feet beyond the threshold. Fly the aircraft on to the runway, do not hold it off or let it “float” to touchdown.

Use autobraking if available. If manual braking is used, maintain adequate brake pedal pressure until a safe stop is assured. Immediately after touchdown, expeditiously accomplish the landing roll procedure.

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Fuel

Fuel Balance

The primary purpose of fuel balance limitations is for the structural life of the airframe and landing gear and not for controllability. A reduction in structural life of the airframe or landing gear can be caused by frequently operating with out-of-limit fuel balance conditions. Lateral control is not significantly affected when operating with fuel beyond normal balance limits.

There is a common misconception among flight crews that the fuel crossfeed valve should be opened immediately after an in-flight engine shutdown to prevent fuel imbalance. This practice is contrary to recommended procedures and could aggravate a fuel imbalance. This practice is especially significant if an engine failure occurs and a fuel leak is present. Arbitrarily opening the crossfeed valve and starting fuel balancing procedures, without following the checklist, can result in pumping usable fuel overboard.

The misconception may be further reinforced during simulator training. The fuel pumps in simulators are modeled with equal output pressure on all pumps so opening the crossfeed valve appears to maintain a fuel balance. However, the fuel pumps in the aircraft have allowable variations in output pressure. If there is a sufficient difference in pump output pressures and the crossfeed valve is opened, fuel feeds to the operating engine from the fuel tank with the highest pump output pressure. This may result in fuel unexpectedly coming from the tank with the lowest quantity.

Fuel Balancing/Crossfeed Considerations

The crew should consider the following when performing fuel balancing procedures:

- Use of the Crossfeed Operation Supplementary Procedure in conjunction with good crew coordination reduces the possibility of crew errors.
- Routine fuel balancing when not near the imbalance limit increases the possibility of crew errors and does not significantly improve fuel consumption.
- During critical phases of flight, fuel balancing should be delayed until workload permits. This reduces the possibility of crew errors and allows crew attention to be focused on flight path control.
- Fuel imbalances that occur during approach need not be addressed if the reason for the imbalance is obvious (e.g. engine failure or thrust asymmetry, etc.).

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Fuel Leak

Any time an unexpected fuel quantity indication, FMS or EOAP fuel message, or imbalance condition is experienced, a fuel leak should be considered as a possible cause. Maintaining a fuel log and comparing actual fuel burn to the flight plan fuel burn can help the pilot recognize a fuel leak.

Significant fuel leaks, although fairly rare, are difficult to detect.

There is no specific fuel leak annunciation on the flight deck. A leak must be detected by discrepancies in the fuel log, by visual confirmation, or by some annunciation that occurs because of a leak. Any unexpected change in fuel quantity or fuel balance should alert the crew to the possibility of a leak. If a leak is suspected, it is imperative to follow the Fuel Leak NNC.

Low Fuel

An EOAP FUEL LEVEL LOW message illuminates when indicated fuel quantity is 2,000 pounds of fuel or less.

Approach and Landing

In a low fuel condition, the clean configuration should be maintained as long as possible during the descent and approach to conserve fuel. However, initiate configuration changes early enough to provide a smooth, slow deceleration to final approach speed to prevent fuel from running forward in the tanks.

A normal landing configuration and airspeed appropriate for the wind conditions are recommended.

Runway conditions permitting, heavy braking and high levels of reverse thrust should be avoided to prevent uncovering all fuel pumps and possible engine flameout during landing roll.

Go-Around

If a go-around is necessary, apply thrust slowly and smoothly and maintain the minimum nose-up body attitude required for a safe climb gradient. Avoid rapid acceleration of the aircraft. If any wing tank fuel pump low pressure light illuminates, do not turn the fuel pump switches off.

Hydraulics

Proper planning of the approach is important. Consideration should be given to the effect the inoperative system(s) has on crosswind capabilities, autoflight, control response, control feel, reverse thrust, stopping distance, go-around configuration, and performance required to reach an alternate airfield.

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Hydraulic System(s) Inoperative - Landing

If the landing gear is extended using manual gear extension, the gear cannot be raised. Flaps can be extended or retracted using a single hydraulic system. However, the rate of flap/slat travel is reduced.

Landing Gear

Braking with Antiskid Inoperative

When the antiskid system is inoperative, the following techniques apply:

- Ensure that the nose wheels are on the ground and the speedbrakes are extended before applying the brakes
- Initiate wheel braking using very light pedal pressure and increase pressure as ground speed decreases
- Apply steady pressure and do not pump the pedals.This is because each time the brakes are released, the required stopping distance is increased. Also, each time the brakes are reapplied, the probability of a skid is increased.

Antiskid-off braking requires even greater care during lightweight landings. Flight testing has demonstrated that braking effectiveness on a wet grooved runway is similar to that of a dry runway. However caution must be exercised when braking on any wet, ungrooved portions of the runway with antiskid inoperative to avoid tire failure.

Note: Do not dispatch with an inoperative antiskid system.

Tire Failure during or after Takeoff

If the crew suspects a tire failure during takeoff, advise ATC of the potential for tire pieces remaining on the runway. The crew should consider continuing to the destination unless there is an indication that other damage has occurred (non-normal engine indications, engine vibrations, hydraulic system failures or leaks, etc.).

Continuing to the destination will allow the aircraft weight to be reduced normally, and provide the crew an opportunity to plan and coordinate their arrival and landing when the workload is low.

Considerations in selecting a landing airport include, but are not limited to:

- Sufficient runway length and acceptable surface conditions to account for the possible loss of braking effectiveness
- Sufficient runway width to account for possible directional control difficulties
- Altitude and temperature conditions that could result in high ground speeds on touchdown and adverse taxi conditions
- Runway selection options regarding “taxi-in” distance after landing

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- Availability of operator maintenance personnel to meet the aircraft after landing to inspect the wheels, tires, and brakes before continued taxi
- Availability of support facilities should the aircraft need repair.

Landing on a Flat Tire

Aircraft are designed so that the landing gear and remaining tire(s) have adequate strength to accommodate a flat nose gear tire or main gear tire. When the pilot is aware of a flat tire prior to landing, use normal approach and flare techniques, avoid landing overweight, and use the center of the runway. Use differential braking as needed for directional control. With a single tire failure, towing is not necessary unless unusual vibration is noticed or other failures have occurred.

In the case of a flat nose wheel tire, slowly and gently lower the nose wheels to the runway while braking lightly. Runway length permitting, use idle reverse thrust. Autobrakes may be used at the lower settings. Once the nose gear is down, vibration levels may be affected by increasing or decreasing control column back pressure. Maintain nose gear contact with the runway.

Flat main gear tire(s) cause a general loss of braking effectiveness and a yawing moment toward the flat tire with light or no braking and a yawing moment away from the flat tire if the brakes are applied harder. Maximum use of reverse thrust is recommended. Do not use autobrakes.

If uncertain whether a nose tire or a main tire has failed, slowly and gently lower the nose wheels to the runway and do not use autobrakes. Differential braking may be required to steer the aircraft. Use idle or higher reverse thrust as needed to stop the aircraft.

A Partial or Gear Up Landing

Land on all available gear. The landing gear absorbs the initial shock and delays touchdown of aircraft body parts. Recycling the landing gear in an attempt to extend the remaining gear is not recommended. A gear up or partial gear landing is preferable to running out of fuel while attempting to solve a gear problem.

Note: A tower fly-by is not recommended.

Landing Runway

Consideration should be given to landing at the most suitable airport with adequate runway and fire fighting capability. Foaming the runway is not Delta Air Lines' policy.

Prior to Approach

If time and conditions permit, reduce weight as much as possible by burning off fuel to attain the slowest possible touchdown speed.

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At the captain's command, advise the crew and the passengers of the situation, as needed. Coordinate with all ground emergency facilities. For example, fire trucks normally operate on a common VHF frequency with the aircraft and can advise the crew of the aircraft condition during the landing. Advise the cabin crew to perform emergency landing procedures and to brief passengers on evacuation procedures.

The NNC instructs the crew to inhibit the ground proximity system as needed to prevent nuisance warnings when close to the ground with the gear retracted.

For landing in any gear configuration, establish approach speed early and maintain a normal rate of descent.

Landing Techniques

Attempt to keep the aircraft on the runway to minimize aircraft damage and aid in evacuation. After touchdown lower the nose gently before losing elevator effectiveness. Use all aerodynamic capability to maintain directional control on the runway. At touchdown speed, the rudder has sufficient authority to provide directional control in most configurations. At speeds below 60 knots, use nose wheel/rudder pedal steering, if available, and differential braking as needed.

Use of Spoilers

If the landing will be made with the nose wheel unsafe and the main gear extended, arm the spoilers for landing. If landing with one or both main gear unsafe, do not arm the spoilers.

When landing with any gear that indicates up or partially extended, attempt to fly the area with the unsafe indication smoothly to the runway at the lowest speed possible, but before losing flight control effectiveness. A smooth touchdown at a low speed helps to reduce aircraft damage and offers a better chance of keeping the aircraft on the runway. The aircraft is easier to control before body parts make ground contact. If the spoilers are deployed before all areas have made contact with the runway, the aircraft will complete touchdown sooner and at a higher speed.

After Stop

Accomplish an evacuation, if needed.

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Gear Disagree Combinations

Both Main Gear Extended with Nose Gear Up

Establish approach speed early and maintain normal rate of descent. After touchdown at the normal 1,000 foot point, manually extend the spoilers if necessary. Use idle reverse thrust with caution. Actuate trim control to nose up to assist in holding nose off runway. Hold nose off until approximately 80 KIAS then lower the nose gently before losing elevator effectiveness. Upon nose contact, use maximum braking (within limits of directional control) to stop aircraft.

Nose Gear Only Extended

Establish a normal approach with maximum flaps (for configuration). Land in the center of the runway. Use normal approach and flare attitude maintaining back pressure on the control column until ground contact. Do not use spoilers during landing.

One Main Gear Extended and Nose Gear Extended

Land the aircraft on the side of the runway that corresponds to the extended main gear down. At touchdown, maintain wings level as long as possible. Use rudder and nose wheel steering for directional control. After all gear have made contact with the runway, braking on the side opposite the unsupported wing should be used as needed to keep the aircraft rolling straight.

One Main Gear Only Extended

Land the aircraft on the side of the runway that corresponds to the extended main gear down. At touchdown, maintain wings level as long as possible. Use rudder for directional control. After all gear, or the nose, have made contact with the runway, braking on the side opposite the unsupported wing should be used as needed to keep the aircraft rolling straight.

All Gear Up or Partially Extended

Use a normal approach and flare attitude.

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Overspeed

VMO/MMO is the aircraft maximum certified operating speed and should not be exceeded intentionally. However, crews can occasionally experience an inadvertent overspeed. Aircraft have been flight tested beyond VMO/MMO to ensure smooth pilot inputs will return the aircraft safely to the normal flight envelope.

During cruise at high altitude, wind speed or direction changes may lead to overspeed events. Although autothrottle logic provides for more aggressive control of speed as the aircraft approaches VMO or MMO, there are some conditions that are beyond the capability of the autothrottle system to prevent short term overspeeds.

When correcting an overspeed during cruise at high altitude, avoid reducing thrust to idle which results in slow engine acceleration back to cruise thrust and may result in over-controlling the airspeed or a loss of altitude. If autothrottle corrections are not satisfactory, deploy partial speedbrakes slowly until a noticeable reduction in airspeed is achieved. When the airspeed is below VMO/MMO, retract the speedbrakes at the same rate as they were deployed. The throttles can be expected to advance slowly to achieve cruise airspeed; if not, they should be pushed up more rapidly.

During descents at or near VMO/MMO, most overspeeds are encountered after the autopilot initiates capture of the VNAV path from above or during a level-off when the speedbrakes were required to maintain the path. In these cases, if the speedbrakes are retracted during the level-off, the aircraft can momentarily overspeed. During descents using speedbrakes near VMO/MMO, delay retraction of the speedbrakes until after VNAV path or altitude capture is complete. Crews routinely climbing or descending in windshear conditions may wish to consider a 5 to 10 knot reduction in climb or descent speeds to reduce overspeed occurrences. This will have a minimal effect on fuel consumption and total trip time.

When encountering an inadvertent overspeed condition, crews should leave the autopilot engaged unless it is apparent that the autopilot is not correcting the overspeed. However, if manual inputs are required, disengage the autopilot. Be aware that disengaging the autopilot to avoid or reduce the severity of an inadvertent overspeed may result in an abrupt pitch change.

During climb or descent, if VNAV pitch control is not correcting the overspeed satisfactorily, switching to the V/S mode temporarily may be helpful in controlling speed. In the V/S mode, the selected vertical speed can be adjusted slightly to increase the pitch attitude to help correct the overspeed. As soon as the speed is below VMO/MMO, VNAV may be re-selected.

Note: Any time VMO/MMO is exceeded, the maximum airspeed should be noted in the logbook.

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Smoke/Fumes Principles

All smoke/fire/fumes events are different, and every contingency cannot be addressed in a single checklist. At the beginning of any smoke/fire/fumes event, crews should always consider the following:

- Protecting themselves (e.g., oxygen masks)
- Communicating (Crew and ATC)
- Diverting
- Assessing the smoke/fire/fumes situation and available resources.

If smoke/fire/fumes are associated with an annunciated checklist (e.g., cargo fire), accomplish that checklist prior to the "SMOKE, FIRE OR FUMES" or "SMOKE OR FUMES REMOVAL" checklists.

Known Source

Many smoke/fire/fumes events involve aircraft equipment or materials readily accessible. Rapid, positive extinguishing of the source is the key to preventing escalation of the event. Confirmation that the situation has been resolved is critical. Do not consider flight continuation unless the source is positively identified, confirmed to be extinguished and smoke/fumes are decreasing.

Unknown Source

It may not always be possible to accurately identify the smoke/fire/fumes source due to ambiguous cues, such as multiple sources. It may not be possible to determine the difference between electrical smoke/fumes and air conditioning smoke/fumes by sense of smell. The source identification/elimination steps in the "SMOKE, FIRE OR FUMES" Checklist will systematically remove the most probable smoke/fire/fumes sources.

Inordinate depowering of airplane systems is not likely to benefit an unknown smoke/fire/fumes situation. Such action significantly reduces airplane capabilities without commensurate likelihood of depowering the unknown smoke/fire/fumes source.

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Smoke/Fumes Priorities

General

The following information is critical to survival in a smoke/fumes situation.

All applicable non-normal checklists can be found in the QRH, Section 8 (Fire Protection).

Note: Pilots should remain at their stations to fly the aircraft, coordinate with ATC and accomplish the checklists. The incapacitation of a pilot fighting a fire would seriously complicate the situation.

Priorities

WARNING: Do not activate the emergency passenger oxygen system. It provides no smoke protection for passengers as it mixes oxygen with cabin air. It is also an extreme fire hazard.

Diversion

After making a preliminary assessment of the smoke/fire/fumes source, the flight crew is reminded that a diversion may be necessary. Landing at the nearest suitable airport is required if smoke or fire continues. For smoke that continues or a fire that cannot be positively confirmed to be completely extinguished, the earliest possible descent, landing and evacuation must be done.

Oxygen Masks/Smoke Goggles (if required)

The flight crew should don the oxygen mask/smoke goggles anytime smoke/fire/fumes are detected on the flight deck. If smoke/fire/fumes are detected in another part of the aircraft, flight crew judgment will determine if/when the oxygen masks/smoke goggles are donned.

Crew and Cabin Communications

For a cabin smoke/fire/fumes situation, continuous communications between the flight crew and a designated flight attendant is essential. Flight attendants should be directed to inspect the entire cabin in an attempt to locate the smoke/fire/fumes source. Passengers should be moved away from the source.

Identification/Elimination

The flight crew should, without delay or analysis, perform the initial "SMOKE, FIRE OR FUMES" checklist steps that remove the most probable smoke/fire/fumes sources. The flight crew should attempt to identify and eliminate the source, and visually confirm it is extinguished and the smoke/fumes are decreasing.

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Removal

The "SMOKE OR FUMES REMOVAL" checklist should be accomplished only when the smoke/fumes are the greatest threat, or when the source is confirmed to be extinguished. Smoke/fumes removal may change the airflow and make the situation worse by fanning or masking the ignition source.

Warning Systems

If an unexpected landing gear configuration or GPWS alert occurs, the flight crew must ensure the proper configuration for the phase of flight. Time may be required in order to assess the situation, take corrective action and resolve the discrepancy. Flight path control and monitoring of instruments must never be compromised.

Note: If the warning occurs during the approach phase, a go-around may be necessary, followed by holding or additional maneuvering.

Windows

Window Damage

To do the Cracked Windshield NNC, the flight crew may need to determine if the inner pane of the affected window is cracked or shattered. This can be done by placing the point of an object such as a pencil on the crack, and then moving the head while focusing on the point of the object. If the crack appears to move relative to the point of the object, the crack is not in the inner pane. If the crack does not appear to move relative to the point of the object, the crack is in the inner pane. A crack in the inner pane may also be detected by running a fingernail across the window's surface.

If the flight crew is uncertain which pane is cracked or shattered, assume that the inner pane is cracked or shattered and continue with the checklist.

If both forward windows delaminate or forward vision is unsatisfactory, accomplish an ILS autoland, if available.

Refer to the QRH, Cracked Windshield NNC.

Flight with the Side Window(s) Open

The inadvertent opening of an unlatched flight deck window by air loads during the takeoff roll is not considered an event that warrants a high-speed RTO. Although the resulting noise levels may interfere with crew communications, it is safer to continue the takeoff and close the window after becoming airborne and the flight path is under control. The flight may be continued once the window is closed and locked and pressurization is normal. If the window is damaged and will not close, return to the departure airport.

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If needed, the windows may be opened in flight after depressurizing the aircraft. It is recommended that the aircraft be slowed since the noise levels increase at higher airspeed. Maneuver speed for the current flap setting is a good target speed. Intentions should be briefed and ATC notified prior to opening the window as the noise level can be high and make communications difficult, even at slow speeds. However, there is very little turbulence on the flight deck. Because of aircraft design, there is an area of relatively calm air over the open window. Forward visibility can be maintained by looking out of the open window using care to stay clear of the airstream.

Situations Beyond the Scope of Non-Normal Checklists

It is rare to encounter in-flight events which are beyond the scope of the recommended NNCs. These events can arise as a result of unusual occurrences such as a midair collision, bomb explosion, or other major malfunction. In these situations the flight crew may be required to accomplish multiple NNCs, selected elements of several different NNCs applied as necessary to fit the situation, or be faced with little or no specific guidance except their own judgment and experience. Because these situations are rare, it is not practical or possible to create definitive flight crew NNCs to cover all events.

The following guidelines may aid the flight crew in determining the proper course of action should an in-flight event of this type be encountered. Although these guidelines represent what might be called “conventional wisdom”, circumstances determine the course of action which the crew perceives will conclude the flight in the safest manner.

Basic Aerodynamics and Systems Knowledge

Knowledge of basic aerodynamic principles and aircraft handling characteristics and a comprehensive understanding of aircraft systems can be key factors in situations of this type.

Basic aerodynamic principles are known and understood by all pilots. Although not a complete and comprehensive list, following is a brief review of some basic aerodynamic principles and aircraft systems information relevant to such situations:

- If aileron control is affected, rudder inputs can assist in countering unwanted roll tendencies. The reverse is also true if rudder control is affected.
- If both aileron and rudder control are affected, the use of asymmetrical engine thrust may aid roll and directional control.

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- If elevator control is affected, stabilizer trim, bank angle and thrust can be used to control pitch attitude. To do this effectively, engine thrust and airspeed must be coordinated with stabilizer trim inputs. The aircraft continues to pitch up if thrust is increased and positive corrective action is not taken by re-trimming the stabilizer. Flight crews should be aware of the aircraft's natural tendency to slowly oscillate in the pitch axis if the stable pitch attitude is upset. These oscillations are normally self damping, but to ensure proper control, it may be desirable to use thrust and/or stabilizer trim to hasten damping and return to a stable condition. The aircraft exhibits a pitch up when thrust is increased and a pitch down when thrust is decreased. Application of thrust induces relatively small pitch moments, especially as compared to aircraft with under wing engines. Pitch change will be more responsive to thrust reductions, than thrust increases. Naturally, airspeed increases without stabilizer trim adjustments will result in higher airspeeds, more lift, and a pitch increase. Small stabilizer trim inputs should be the primary method of establishing desired pitch when the elevator is inoperative, as thrust has small moment effect. Small inputs of trim, or thrust, should be separated by some length of time, which is necessary for the crew to be able to recognize the resultant effects. This is the most effective way to stabilize the pitch oscillations (the Phugoid). These pitch oscillations are subject to excitation from both internal (pilot input), and external inputs (turbulence, or wind value changes, primarily).
- A flight control break-out feature is designed into all Boeing aircraft. If a jammed flight control exists, both pilots can apply force to either clear the jam or activate the break-out feature. There should be no concern about damaging the mechanism by applying too much force. In certain cases, clearing the jam may permit one of the control columns to operate the flight controls with portions of a control axis jammed. It may be necessary to apply break-out forces for the remainder of the flight on the affected control axis.
- Stall margin decreases with angle of bank and increasing load factors. Therefore, it is prudent to limit bank angle to 15° in the event maneuver capability is in question. Increasing the normal flap/speed maneuver schedule while staying within flap placard limits provides extra stall margin where greater bank angles are necessary.
- All Delta Air Lines' aircraft have the capability to land using any flap position, including flaps up. Use proper maneuver and final approach speeds and ensure adequate runway is available to stop the aircraft after landing.

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Flight Path Control

When encountering an event of the type described above, the flight crew's first consideration should be to maintain or regain full control of the aircraft and establish an acceptable flight path. This may require use of unusual techniques such as the application of full aileron or rudder, or in an asymmetrical thrust situation, reduction of thrust on the operating engine(s) to regain lateral control. This may also require trading altitude for airspeed or vice versa. The objective is to take whatever action is necessary to control the aircraft and maintain a safe flight path. Even in a worst case condition where it is not possible to keep the aircraft flying and ground contact is imminent, a "controlled crash" is a far better alternative than uncontrolled flight into terrain.

If the operation of flaps is in doubt, leading and trailing edge flap position should not be changed unless it appears that aircraft performance immediately requires such action. Consideration should be given to the possible effects of an asymmetrical flap condition on aircraft control if flap position is changed. If no flap damage exists, wing flaps should be operated as directed in the associated NNC. Any time an increasing rolling moment is experienced during flap transition, return the flap handle to the previous position.

Unusual events adversely affecting aircraft handling characteristics while airborne may continue to adversely affect aircraft handling characteristics during landing ground roll. Aggressive differential braking and/or use of asymmetrical reverse thrust, in addition to other control inputs, may be required to maintain directional control.

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Checklists with Memory Steps

After flight path control has been established, do the memory steps of the appropriate NNC. The emphasis at this point should be on containment of the problem. Reference steps are initiated after the aircraft flight path and configuration are properly established.

Complete all applicable NNCs, prior to beginning final approach. Exercise common sense and caution when accomplishing multiple NNCs with conflicting directions. The intended course of action should be consistent with the damage assessment and handling evaluation.

Communications

Establish flight deck communications as soon as possible. This may require use of the flight deck interphone system or, in extreme cases of high noise levels, hand signals and gestures in order to communicate effectively.

Declare an emergency with Air Traffic Control (ATC) to ensure priority handling and emergency services upon landing. Formulate an initial plan of action and inform ATC. If possible, request a discrete radio frequency to minimize distractions and frequency changes. If unable to establish radio communication with ATC, squawk 7700 and proceed as circumstances dictate.

Communications with the cabin crew and with company ground stations are important, but should be accomplished as time permits. If an immediate landing is required, inform the cabin crew as soon as possible.

Damage Assessment and Aircraft Handling Evaluation

Unless circumstances such as imminent aircraft breakup or loss of control dictate otherwise, the crew should take time to assess the effects of the damage and/or conditions before attempting to land. Make configuration and airspeed changes slowly until a damage assessment and aircraft handling evaluation have been done and it is certain that lower airspeeds can be safely used. In addition, limit bank angle to 15° and avoid large or rapid changes in engine thrust and airspeed that might adversely affect controllability. If possible, conduct the damage assessment and handling evaluation at an altitude that provides a safe margin for recovery should flight path control be inadvertently compromised. It is necessary for the flight crew to use good judgment in consideration of the existing conditions and circumstances to determine an appropriate altitude for this evaluation.

The evaluation should start with an examination of flight deck indications to assess damage. Consideration should be given to the potential cumulative effect of the damage. A thorough understanding of aircraft systems operation can greatly facilitate this task.

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If structural damage is suspected, attempt to assess the magnitude of the damage by direct visual observation from the flight deck and/or passenger cabin. While only a small portion of the aircraft is visible to the flight crew from the flight deck, any visual observation data can be used to gain maximum knowledge of aircraft configuration and status and can be valuable in determining subsequent actions.

The flight crew should consider contacting the company to inform them of the situation and use them as a potential source of information. In addition to current and forecast weather, and airfield conditions, it may be possible to obtain technical information and recommendations from Delta Air Lines and the aircraft manufacturer.

If controllability is in question, consider performing a check of the aircraft handling characteristics. The purpose of this check is to determine minimum safe speeds and the appropriate configuration for landing. If flap damage has occurred, prior to accomplishing this check, consider the possible effects on aircraft control should an asymmetrical condition occur if flap position is changed. Accomplish this check by slowly and methodically reducing speed and lowering the flaps. Lower the landing gear only if available thrust allows.

As a starting point, use the flap/speed schedule as directed in the appropriate NNC. If stick shaker or initial stall buffet are encountered at or before reaching the associated flap speed, or if a rapid increase in wheel deflection and full rudder deflection are necessary to maintain wings level, increase speed to a safe level and consider this speed to be the minimum approach speed for the established configuration.

After the damage assessment and handling characteristics are evaluated, the crew should formulate a sequential plan for the completion of the flight.

If aircraft performance is a concern, use of the alternate flap or gear extension systems may dictate that the check of aircraft handling characteristics be done during the actual approach. Configuration changes made by the alternate systems may not be reversible. The crew must exercise extreme caution on final approach with special emphasis on minimum safe speeds and proper aircraft configuration. If asymmetrical thrust is being used for roll control or pitch authority is limited, plan to leave thrust on until touchdown.

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Landing Airport

The following items should be considered when selecting an airport for landing:

- Weather conditions (VMC preferred)
- Enroute time,
- Length of runway available (longest possible runway preferred, wind permitting)
- Emergency services available
- Flight crew familiarity
- Other factors dictated by the specific situation.

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Human Factors
Table of Contents

Overview **9.1**

History of CRM and TEM **9.1**

Crew Resource Management **9.2**

CRM Skills 9.3

Error 9.8

Error Management 9.11

Practical Application of TEM Process **9.12**

Threat Management Tools 9.12

The Highest Threat 9.13

Unexpected Threat Management Tool 9.14

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Human Factors Chapter 9

Overview

This chapter is designed to provide the crewmember with a practical guide on how to better incorporate CRM procedures and Threat Management behaviors on the flight deck to reduce operational errors.

History of CRM and TEM

In 1978, a United Airlines DC8 crew requested a delay before landing due to a gear malfunction. While troubleshooting the malfunction they failed to monitor their fuel which led to fuel starvation, and they crashed near Portland, OR. The roots of Human Factors, Crew Resource Management (CRM) and Threat and Error Management (TEM) can be traced to a 1979 NASA workshop formed to research the causes of air transport accidents such as this DC8. Research presented at this meeting identified the human error aspects (Human Factors) of the majority of air crashes as failures of interpersonal communications, decision making, and leadership. At this meeting the label Cockpit Resource Management, later changed to Crew Resource Management, was applied to the process of training crews to reduce pilot error by making better use of the human resources on the flight deck.

CRM training programs have evolved in the years since the NASA meeting. First generation courses were broad in nature, with a heavy focus on psychological testing and general concepts such as leadership. These courses advocated general strategies of interpersonal behavior without providing clear definitions of appropriate behavior in the flight deck. Games and exercises, unrelated to aviation, were employed to illustrate concepts.

Five generations of CRM training later, CRM interpersonal skills are clearly defined. Combined with Delta Safety Management System (SMS) data from FOQA and ASAP, CRM skills are being used to proactively mitigate threats and manage errors (TEM). Within Delta's SMS, Human Factors is the science that defines CRM skills through a process called TEM.

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Crew Resource Management

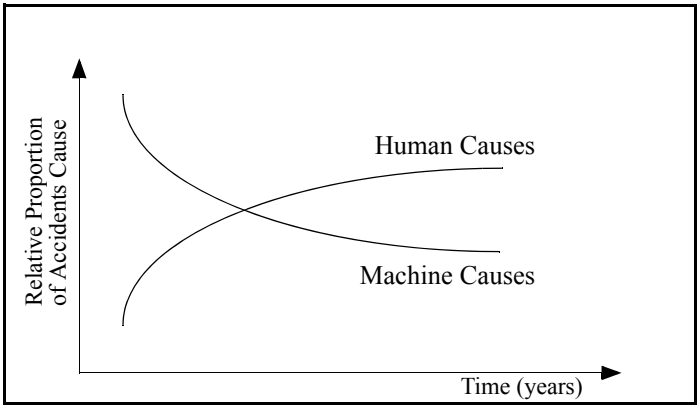
CRM is a discipline within the larger field of Human Factors and can be defined as the effective use of all resources, including hardware, software, and people, to achieve the highest possible level of safety. The use of CRM enhances the safety and effectiveness of your crew (pilots and flight attendants) as well as the expanded team (Flight Control, Line Maintenance, Ramp Service, etc.).

- Crew = pilots and flight attendants.
- Resource = people, skills, equipment, and services.
- Management = directing, controlling, and coordinating.

Experience and research show that crews with effective CRM skills more ably mitigate threats and reduce the likelihood of making errors. Thus, the goal of Delta Flight Operations CRM and TEM programs is to build defenses that reduce the likelihood of error and when necessary mitigate or fix committed errors.

The following figure illustrates the causal factors in civil aviation accidents:

Changes in Accident Causal Factors Over Time
(ICAO, 1984)



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CRM Skills

Delta Flight Operations defines a set of behaviors that affect the performance of pilots as crewmembers and more importantly of the crew as a whole. This set of behaviors are referred to as CRM skills. Each skill represents a desired behavior to be practiced during training and line operations. The CRM skills are divided into seven broad categories: Communication, Workload Management, Planning, Situational Awareness, Decision Making, Threat and Error Management, and Professional Management.

Communication

Effective CRM begins with effective communication. Communications are the verbal and nonverbal activities that represent the transfer of information to and from the flight crew.

- **Conduct thorough briefings.**
- Briefings should be given throughout the flight to address pertinent safety and operational issues, as necessary. They provide guidelines for crew actions, including operating procedures, distribution of crew workload, and any anticipated deviations.
- The captain sets the tone for the team during the flight attendant briefing by emphasizing the importance of interactive decision making and participation by the entire crew, thus encouraging crewmembers to voice any concerns they may have.
- **Clearly communicate operational decisions.**
- Crewmembers should clearly state operational decisions. The captain shares the parameters of operation with the entire crew throughout the flight and the crew contributes their perspectives. Minimum acceptable standards for safe operation (or “bottom lines”) are established and communicated. Likewise, the pilot flying (PF) ensures the pilot monitoring (PM) is kept apprised of current and intended flight actions.
- **Explicitly encourage participation**
- The captain encourages participation by the entire crew and emphasizes the importance of crew interaction in maintaining a safe operation. Crewmembers are encouraged to ask questions about crew actions and decisions.
- **Seek information and direction from others when necessary.**
- Crewmembers recognize personal limitations, such as limited experience in a particular seat or aircraft. When needed to solve operational issues or make decisions, these limitations are mitigated by actively seeking direction or advice from each other. Confusion on the flight deck is minimized by using sufficient inquiry to remain informed.

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- **Assert with appropriate level of persistence as required to maintain a safe operation.**
- Crewmembers state their ideas, opinions, and recommendations, asserting themselves and advocating their point of view as required to maintain safety of flight.
- At times personality differences affect crewmember interaction, especially when combined with a change in organizational culture. To deal with these, a five-step assertive statement process has proven effective.
  - Opening or attention getter - Address the individual. “Hey Chief,” or “Captain Smith,” or “Bob,” or whatever name or title will get the person's attention.
  - State your concern - State what you see in a direct and unemotional manner. “We're low on fuel.”
  - State the problem as you see it - “I don't think we have enough fuel to fly around this storm system.”
  - State a solution - “Let's divert to another airport and refuel.”
  - Obtain agreement (or buy-in) - “Does that sound good to you, Captain?”
- **Critique self and other crewmembers, when appropriate.**
- Continually assess performance to improve the operation on the flight deck. Feedback may be of a positive or negative nature. Feedback should be specific, based on observation, and provided for the purpose of maximizing crew effectiveness.

Situational Awareness

Situational Awareness is the pilot's ability to monitor or perceive elements in the environment, the comprehension of their meaning, and the projection of their status in the near future. This includes physical relationships (e.g. proximity to mountainous terrain), but it can also include other environmental circumstances.

- **Monitor, assess, and share all relevant operational factors to remain situationally aware.**
- Crewmembers monitor, assess, and share with other crewmembers climatic conditions, traffic, internal and external communications, aircraft instruments and performance, automated systems, and all other relevant operational factors to maintain situational awareness. Such information may be used to determine potential changes in operation.
- Complacency and fatigue undermine situational awareness. Combat these threats by diligently accomplishing repetitive/routine tasks and cooperatively monitoring other crewmembers' actions; challenge one another to ensure heightened awareness.

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Planning

- **Anticipate and select a strategy.**
- Planning is the anticipation and selection of actions and strategies to meet current and future operational requirements. Captains should focus the crew's attention on upcoming requirements/demands and divide planning tasks and responsibilities amongst crewmembers. Ask for clarification when plans are not clear.
- As a guide:
  - remain ahead of the aircraft and situation;
  - adapt to changes and factors that affect the current or future flight status;
  - plan and prebrief crew tasks, the operational prioritization of upcoming tasks, and the levels, modes, and configurations of automation to be used; and
  - execute plans as briefed or communicate changes/deviations from the plan.

Decision Making

- **Determine the best course of action.**
- Decision making is the systematic approach to determine the best course of action in response to a given set of circumstances and involves the prioritized, appropriate use of resources both inside and outside the aircraft. Though captains are the final decision making authority, good decision making emphasizes the crew's involvement in the decision-making process. Decisions should be made in a timely and competent manner and conveyed to the entire crew.
- Effective, safety-minded decisions utilize explicit guidance and are not biased regarding competing goals. Poor decisions often result when the crew has time constraints, outside pressure (e.g. Flight Control, Maintenance, personal desires), or lack of experience.
- It is extremely important for crews to recognize when expanding the team is necessary in making the most informed decision. Examples of this are utilization of the Security Conflict Team during security incidents and Maintenance Control Center (MCC) for complex MELs or for multiple equipment failures while airborne.
- Captains are the final decision makers; take command, be decisive, and do not hesitate to make the difficult decisions to ensure the safety of your passengers and crew. If you involve the expanded team when necessary, make informed decisions, and use your best judgment - the Flight Operations management team will always support your decision.

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Workload Management

- **Distribute tasks to maximize efficiency and effectiveness.**
- Workload management describes the distribution of workload so that everyone is utilized and no one is overtaxed. In addition, it facilitates teamwork in a coherent and unified manner. Recognize and report work overload in yourself and in others. Effective workload management results in a well coordinated crew.
- Use all available resources to accomplish required tasks in the most efficient and effective way. Resources may include flight crew, cabin crew, deadheading crewmembers, as well as external resources. Examples of external resources include Flight Control, ATC, and Maintenance. To decrease workload, use aircraft automation whenever appropriate.
- **Prioritize tasks for effective accomplishment.**
- The crew clearly prioritizes operational tasks. Primary tasks, such as continuing to fly the aircraft, are allocated sufficient resources before assessing secondary duties, such as external communications.
- Ensure that low priority or non-essential activities such as social interaction do not interfere with more important tasks.
- **Manage time for accomplishing tasks.**
- The crew allows sufficient time to accomplish flight duties. They recognize the need for and create additional time to complete tasks when operational considerations dictate. Crewmembers are not rushed in the discharge of their duties.

Professional Management

Professional Management allows pilots to maximize individual and team performance to minimize risk.

Professional management skills focus on individual interactions in a team environment and help identify personality traits and cultural differences that affect individual and team performance.These cultural differences and personality traits can harbor threats that are latent and by their very nature difficult to predict, identify, and mitigate. Common latent threats to be aware of include: Power Distance, Individualism/Collectivism, Uncertainty Avoidance, Complacency, Fatigue, and Stress.

- **Power Distance -** Is defined as one's perception and response to hierarchy, seniority or rank. Power Distance is subdivided into High Power Distance and Low Power Distance. High Power Distance exists when first officers do not question a captain's decision or articulate disagreement. Low Power Distance exists when captains and first officers are considered nearly equal in their roles and responsibilities.

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- **Individualism/Collectivism** - Refers to whether a person's goals are self-oriented (individualism) or team-oriented (collectivism). This orientation impacts a pilot's willingness to appropriately operate in a team environment.
- **Uncertainty Avoidance** - Is defined as the threat level perceived during high stress events. High Uncertainty Avoidance involves a preference for standard operating procedures and leaving as little as possible to chance. Low Uncertainty Avoidance involves acceptance of high stress and higher exposure to risk as part of the job, with more tolerance and flexibility.
- **Complacency** - Often referred to as 'the silent killer,' the pilot is unaware that complacency is occurring. There is a feeling of contentment or self-satisfaction that is especially problematic when coupled with an unawareness of actual danger, trouble, or deficiencies. Example: Routine takeoff on a familiar runway and at the hub airport. Remedy: Adopt a diligent and alert attitude towards accomplishing repetitive routine tasks and develop methods of challenging the awareness of other crewmembers.
- **Fatigue** - Physiological studies and real-world experience both validate the negative effects on pilot performance of performing duties while fatigued. While scheduling and crew rest policies endeavor to mitigate the worst impacts of fatigue, responsibilities for personal habits and maintaining a disciplined approach to limiting the effects of fatigue also reside with the pilot. In addition, when fatigue is noted in one's self or another crewmember simply recognizing the situation and advising the other crewmember(s) can be an effective mitigation strategy. If fatigue is a certainty, and it cannot be effectively mitigated, and you believe that it would compromise the safety of flight, then the flight should not be attempted and Crew Scheduling and the chief pilot should be contacted. It is the pilot's responsibility to be properly rested, but it is also the pilot's responsibility to recognize the existence and impacts of fatigue and handle it appropriately.
- **Stress** - Closely related to and contributory to fatigue, stress stems from a range of sources including life events, physical conditions, time constraints, and a host of others. Like fatigue, it is essential for pilots to recognize when stress has the potential to negatively impact performance and to consider mitigation strategies to minimize its effects such as proactively monitoring one another for signs of distraction and communicating concerns clearly.

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Threat and Error Management (TEM)

- TEM is the effective management of Expected and Unexpected Threats using Delta's Threat and Error Management (TEM) process. TEM involves crewmembers proactively identifying threats and vigilantly identifying errors and managing those threats and errors before they impact the safety of flight.
- **Expected Threats** - Threats that are anticipated to effect operations are known as expected threats. Examples of expected operational threats are: adverse weather, MCOs, runway conditions, terrain, complex taxi instructions, a challenging SID or Company Page. (Note: These types of threats are currently considered and briefed during the WARTS and NATS briefs). Examples of expected latent threats are: fatigue after a short layover, complacency on a routine takeoff or arrival a crewmember has accomplished hundreds of times. (Note: These types of threats are currently not considered as part of the WARTS and NATS briefs).
- **Unexpected Threats** - Threats that cannot be anticipated or planned for in advance are known as unexpected threats. Examples of unexpected operational threats are: abnormals, system malfunctions, passenger medical issues, and security threats. Examples of unexpected latent threats are fatigue during a long flight, similar sounding call signs, and complacency.

Error

An error is an action or inaction by the flight crew that leads to deviations with undesired or unexpected consequences. Error management is the process of understanding that errors will occur during operations; emphasis is then placed on crewmember vigilance and effective monitoring/crosschecking so the error is identified or trapped in a timely manner and then mitigated. The importance of the role of the pilot monitoring (PM) in trapping errors is emphasized later in this section.

Errors are defined as flight crew actions or inactions that:

- lead to a deviation from crew or organizational intentions or expectations,
- reduce safety margins, and
- increase the probability of adverse operational events on the ground or during flight.

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Error Types

Aircraft Handling Errors	Examples
Automation	Incorrect altitude, speed, heading, autothrottle settings, mode execution, or FMC entries
Flight Control	Incorrect flaps, speed brake, autobrake, thrust reverser, or power settings
Ground Navigation	Attempting to turn down wrong taxiway/runway; Missed taxiway/runway/gate
Manual Flying	Hand flying vertical, lateral, or speed deviations; Missed runway/taxiway failure to hold short, or taxi above speed limit
Systems/Radio/Instruments	Incorrect pack, altimeter, fuel switch, or radio frequency settings

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Procedural Errors	Examples
Briefings	Missed items in the brief, omitted departure, takeoff, approach, or crew change briefing
Callouts	Omitted takeoff, descent, or approach callouts
Checklist	Performed checklist from memory or omitted checklist; Missed items, wrong challenge and response, performed late or at wrong time
Documentation	Wrong weight and balance, fuel information, ATIS, or clearance recorded; Misinterpreted items on paperwork
Pilot Flying (PF)/ Pilot Monitoring (PM) Duty	PF makes own automation changes while hand flying, PM doing PF duties, PF doing PM duties
SOP Cross-verification	Intentional and unintentional failure to cross-verify automation inputs
Decision-Making Errors	Un-warranted high-speed aborts
Other Procedural	Other deviations from government regulations, flight manual requirements, or standard operating procedures

Communication Errors	Examples
Crew to External	Missed calls, misinterpretation of instructions, or incorrect read-backs to ATC. Wrong clearance, taxiway, gate, or runway communicated
Pilot to Pilot	Within-crew miscommunication or misinterpretation

Unmanaged or mismanaged errors can lead to an undesired aircraft state (e.g., off altitude, off airspeed, off course, or being in the wrong place at the wrong time).

In addition to the types of errors described above, errors can be classified into three categories, decision errors, skill-based errors, and perceptual errors.

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Decision Errors

Decision errors are often procedural in nature. Aviation is very structured and has standard policies and procedures. In this type of error the crew either misapplied the procedure or used an inappropriate action that led to the error. Poor choice errors occur when the crew has time constraints, outside pressure, or lack of experience. These can also be thought of as knowledge-based errors as the crew finds themselves in a situation that they neither understand nor has ever faced before and the situation has exceeded their ability. In many cases the crew can slow the pace and use methodical reasoning to deal with the problem. In other cases decisions have to made immediately, such as in the decision to abort or continue a takeoff.

Skill-based Errors

A skill-based error occurs when the crewmember knows the correct procedure, tries to perform it correctly, but makes a mistake. These types of errors are unintentional, and can be considered proficiency related. Examples of this kind of error are an omitted checklist item or an unstable approach resulting from deficiencies in technical proficiency.

Perceptual Errors

Perceptual errors are caused by visual illusions, spatial disorientation/vertigo or misjudged distance, altitude, airspeed, or clearance.

Error Management

Strict adherence to Delta's approved checklists, procedures, and policies is essential in mitigating operational errors. Additionally, the role of the Pilot Monitoring (PM) has evolved and is now paramount to further manage operational errors.

The original concept of the Pilot Not Flying (PNF) was a supporting crewmember to assist the Pilot Flying (PF). Research performed by NASA Ames Research Center indicated a change from the passive role of PNF to a more assertive role of Pilot Monitoring (PM).

This concept focuses on the second pilot as not only supporting the PF but, as a fully qualified pilot, mentally following the PF in a monitoring task. As a monitoring pilot, the PM would catch those errors the PF might inadvertently make due to any number of reasons. Recent incidents indicate a more assertive role is necessary for the PM. The NTSB found that many of these recent incidents were due to the failure of the Monitoring Pilot to actively monitor.

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This suggests the notion that monitoring can be either passive or active. In these incidents the PM was passively monitoring or not monitoring at all during critical flight segments. The question is why? Research on flight crew error points towards two areas of error in highly skilled pilots; interruptions/distractions and active monitoring. Just as CRM has evolved to Threat & Error Management, Error Management is evolving to proactive strategies such as active monitoring by the PM.

Practical Application of TEM Process

Threat Management Tools

Delta's Threat Management Process is an ordering of CRM skills that help the crewmember proactively mitigate threats to safe operations. These tools are offered to crewmembers as a method of mitigating threats by planning in advance for those that are expected, and simplifying the process for handling those that are unexpected. Data indicates that crews who proactively deal with threats make fewer errors than crews who react to threats as they occur.

Currently, separate Threat Management tools exist for both expected and unexpected threats.

Expected Threat Management Tool

Studies have shown that the greatest concentration of threats exists between pushback thru top-of-climb, and then again from top-of-descent thru taxi to the gate. In addition to all the normal latent threats such as stress, complacency and personality conflicts, these flight segments contain operational threats such as airport irregularities, weather and complex departures/arrivals that require pilot attention. Crewmembers must identify expected (known) threats before each flight segment, plan for each threat, and communicate the plan to other crewmembers. The Threat Management tools for this purpose are the W-A-R-T-S and N-A-T-S briefings described in FOM chapter 3.

When conducting these briefings, be sure to include the expected threats in each major category, and the plan to mitigate each threat. WARTS and NATS refer to operational threats but crews should also include latent threats (complacency, stress, fatigue) and plans to mitigate such threats in their Departure and Approach briefings as necessary.

Threat management tools, WARTS and NATS, incorporate all of Delta's seven CRM skills:

- Situational Awareness - Threats identified through proper situational awareness.
- Decision Making - Pilot flying decides which threats to brief and identifies highest threat for the flight segment.
- Planning - Plan is made to mitigate the threats.

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- Communication - Plans are communicated to other crewmembers and expanded team members.
- Workload Management - Briefings are accomplished during periods of low workload (e.g. at the gate or before top of descent).
- Threat and Error Management - Is the effective management of expected and unexpected threats using Delta's Threat and Error Management (TEM) process.
- Professional Management - Allows pilots to maximize individual and team performance to minimize risk.

The Highest Threat

While it is a sound TEM practice to identify expected threats and communicate plans to mitigate those threats, pilots should verbalize the highest threat to each flight segment, as stated in FOM, chapter 3. The purpose of identifying the highest threat from those threats already briefed is twofold. First, a critical element to TEM is the constant evaluation and prioritizing of threats by the crewmembers. While a crew may have briefed several threats during a WARTS Departure brief, there is value in mentally reviewing those threats and prioritizing which among them is most likely to negatively affect the flight. Verbalizing this threat at the end of the briefing separates it out from the others and emphasizes its importance.

Secondly, it is possible that the highest threat is a latent threat that was not included in WARTS or NATS. This is a likely scenario for many crews who have vast experience departing from or arriving to a particular airport or runway (e.g. T/O from KATL Rwy 08R). For example: "The highest threat for today is complacency and the plan to mitigate this threat is to simply recognize that we are susceptible and to realize that today might be the day that the departure does not go as planned."

Note: It is not necessary to re-brief the plan to mitigate the highest threat if it was previously covered in WARTS or NATS.

It is critically important to remember to brief a mitigation plan for each threat, but it is especially important in regards to the highest threat. For example, when departing an airport with high terrain in the vicinity, it would be appropriate to brief: terrain location in relation to the planned departure route, the use of terrain mapping in an effective range, the MSA, grid MORA and the Company Pages for special engine out departure procedures. Additionally, a review of terrain avoidance procedures for GPWS alerts and warnings would be warranted.

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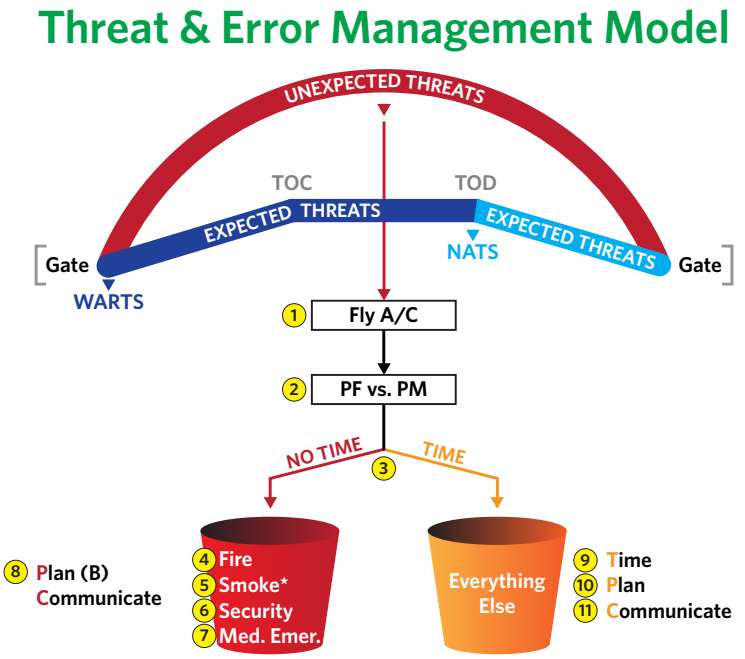
Unexpected Threat Management Tool

Unlike expected threats that can be planned for in advance, unexpected threats can occur at any time from initial pushback from the gate to block-in at the destination. Generally, pilots react to these types of threats as they occur, using their CRM skills acquired from past experience or training. The goal of Delta TEM is to give pilots a CRM process to proactively handle these threats and manage resultant error. Properly utilized, this threat management process enables crews to know what to do to manage a threat before it occurs. The following TEM model orders crew CRM skills into a process that allows the crew to proactively manage both expected and unexpected threats.



(1) Flying the aircraft is the top priority. After assuring aircraft control, stabilize the situation by accomplishing immediate action items (if applicable), offsetting from NAT tracks or WATRS routes (in case of engine failure), etc. Use of automation is highly encouraged.

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(2) Decision Making, Workload Management - The captain should divide the flight deck and assign duties. Any one crewmember that attempts to fly the aircraft, respond to ATC and respond to a non-normal event (manage the threat) risks task saturation and creates the potential for error. Under normal circumstances, effective workload management might divide crewmember duties as follows:

- PF - Primary responsibilities are to fly the aircraft, listen, respond and adhere to ATC clearances. Maintain situational awareness through periodic communication with PM. Involve PM if any problems or difficulties are encountered.
- PM - Primary responsibilities are to maintain constant situational awareness, prioritize threats, manage the highest threat by building (expanding) a CRM team for input, create enough time to formulate a plan of action, communicate that plan as necessary and continue to actively monitor the PF as able.

The captain (as pilot in command) must make several decisions in the course of managing the threat (build the CRM team and solicit input, evaluate options, decide on where to land, etc.). This suggests that, under many circumstances, the captain should assume the PM role when faced with an unexpected threat. (Exceptions to this situation might include a low time first officer in mountainous terrain, an uncontrollable aircraft, etc.)

Additionally, extensive analysis in the simulator during LOEs confirms an increase in crew errors when the captain assumes the PF role and attempts to manage the threat while simultaneously controlling the aircraft. This is corroborated by an NTSB study from 1979-1994 which determined that in 81% of aircraft incidents during that time period the captain was the PF.

Note: Nothing expressed in the preceding paragraphs supersedes in any way the captain's emergency authority to take any and all action, including the assignment of PF/PM duties during non-normal situations, to provide for the safety of the passengers and crew. The captain should recognize, however, that attempting to manage a threat while controlling the aircraft increases the chance of error and he/she should consider further steps to mitigate these errors (e.g., creating more time to consider a plan of action, increased use of automation, remaining in protected airspace while dealing with the threat by entering holding, etc.)

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(3) Decision Making - After the captain assigns PF duties to the first officer, he or she must pause to determine the criticality of the highest threat before assigning a TIME or NO TIME designation. This may require expanding the team, such as contacting STAT-MD when evaluating the criticality of a medical event.

Note: ASAP data indicates captains may overlook this step, particularly in misdiagnosing a medical event as a medical emergency. Take the time to expand the team if necessary (i.e. contact STAT-MD for a medical event) before choosing a TIME or NO TIME threat management path.

NO TIME Threats - Include unexpected threats that are time critical in nature and usually require landing as soon as safely possible.

- NO TIME threats require that the captain have a plan of action in mind (Plan B) to enact as soon as the threat occurs.
- NO TIME threats may be aircraft specific. For example, a simple engine failure in a Cessna 150 would be considered a NO TIME threat where it is not in a B747. NO TIME threats listed here are common to all Delta aircraft. Individual fleets may consider additional NO TIME threats based on the needs of their particular type of aircraft.
- NO TIME threats may be flight segment specific and are not listed in the TEM model. Examples of these threats are engine failure on a WATRS route and rapid depressurization over critical terrain. Threats of this type and an intended plan of action (Plan B) must be pre-briefed by the crew prior to each applicable flight segment.
- Even during a NO TIME threat, TEM never has an aircraft land as soon as possible, but rather as soon as is safely possible.

(4) Fire - Fires of an unknown origin, intensity or disposition should always be considered a NO TIME Threat. Even fires that appear to be extinguished may have caused unknown damage to components and landing should not be delayed (exception, lavatory waste fire, etc.)

(5) Smoke - Delta policy allows for time to evaluate a smoke threat before determining the criticality of the threat. For example, the crew may elect to continue a flight if the smoke is from an extinguished lavatory trash bin fire. Refer to chapter 8, Non-Normal Operations, Smoke/Fumes Principles and Smoke/Fumes Priorities for further information.

(6) Security - Refer to FOM, 4.4, Sensitive Security Information, Common Strategy for further information.

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(7) Medical Emergency - Delta policy is to contact STAT-MD to determine the criticality of a medical event. STAT-MD is to be considered primary guidance in the decision to upgrade a medical event to a medical emergency. An expedited landing or diversion to an alternate airport should not be commenced before contacting STAT-MD (unless contacting STAT-MD will delay landing at the destination airport). Refer to FOM, 7.4, Medical Emergencies, for further information.

(8) Plan (B) suggests that each captain have a plan of action in mind before an actual NO TIME event occurs. Captains should always have an emergency divert field in mind from takeoff through landing for each flight. Updates to this alternate destination should be made periodically throughout the flight as necessary due to location of the aircraft, suitability of the alternate airport (Refer to Airway Manual, Airport Directory & Authorization) and weather.

Note: Although it is essential that captains always have a divert field in mind, the actual decision to divert and the most suitable alternate should be determined in conjunction with the dispatcher and STAT-MD (for a medical emergency).

Upon determining that an expedited landing must be made, the captain could use the following Plan (B):

"F/O you have the aircraft and the radios. Declare an emergency. Take the aircraft to (designated alternate airport), longest landing runway, 10NM final, 200kts. Go as fast as you are comfortable but no faster, and get my attention if you run into any problems or have any questions. Do you have any questions now?"

This plan exemplifies the CRM skills of workload management, decision making, planning and communication and allows the captain to focus on the threat at hand while maintaining critical Situational Awareness. Calmly communicated, this plan effectively manages the non-normal workload, ensures someone is flying the aircraft, is decisive, and sets the aircraft up for a stabilized approach. It is also a plan that can be proactively memorized by all captains.

Note: The preceding Plan (B) is used as an example only. It is only important that each captain have some plan of action in mind before encountering any NO TIME threats.

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TIME Threats - Include any threat to safe operation of the flight that is not time critical in nature. Examples of these threats are medical events, most aircraft system malfunctions, deteriorating weather conditions, late runway changes, etc.

- TIME threats are not critical in nature and allow the crew time to fully evaluate a new plan of action.
- The vast majority of threats to crewmembers are TIME threats. Crews should recognize that very often they either have ample time or the ability to create additional time to effectively manage most threats to the operation.
- Misdiagnosing a TIME threat as a NO TIME threat (particularly upgrading a medical event to a NO TIME medical emergency without contacting STAT-MD) and rushing through a plan of action (i.e. non-normal checklists) are two of the most common errors crewmembers make.

(9) Time - Create more time to consider a plan of action. Ways to create more time are often dictated by phase of flight and include:

- Slow down
- Request vectors
- Enter holding

Note: Crews must consider fuel load when creating time to make a plan.

(10) Plan - Expand your CRM team (other crewmembers, dispatch, STAT-MD, maintenance, deadhead crew, flight attendants, etc.) and use your onboard resources (QRH, Volume 1, ODM, etc.) to formulate a plan of action.

(11) Comm - Communicate the plan of action as necessary (2 in 2 out) meaning, communicate the plan to the flight attendants and passengers (2 in) and to ATC and the company (2 out).

Note: The captain must always maintain Situational Awareness, including during the implementation of the TPC model. Dynamic flight situations often present multiple threats which must be continuously considered and evaluated throughout the flight. It is possible that the TPC model will be interrupted and run again to address subsequent, more challenging threats.

Example: An engine fire (NO TIME) results in an expedited divert to a 10 mile final. The fire appears to be extinguished yet the crew finds itself unprepared to complete the approach (now the highest threat). The captain requests a 360-degree turn (TPC) to create time to prepare for the approach.

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Selected References — Chapter 10
Table of Contents — Section TOC

Engine Out. 10.1
Engine Failure Takeoff Performance 10.1
Takeoff Segments 10.2
Departure Procedures (DPs) 10.3

High Elevation Considerations 10.7
Aircraft Performance Characteristics 10.7
Stopping Dynamics 10.8

Performance Considerations 10.9
Factors Affecting Takeoff Performance 10.9
Factors Affecting Landing Performance 10.10
Climb Performance 10.11
Turning Performance. 10.12

Weather Radar 10.14
Turbulence Avoidance 10.14
Windshear Avoidance 10.16

Hydroplaning 10.17
Dynamic Hydroplaning 10.17
Viscous Hydroplaning. 10.19
Steam Hydroplaning (Reverted Rubber). 10.19
Controllable Physical Factors 10.20
Flight Deck Considerations and Techniques. 10.21

Delta Maneuver Training 10.23
Aerodynamic Aspects of Maneuver 10.23
Flight Dynamics 10.24
Structural Aspects of Maneuver 10.32

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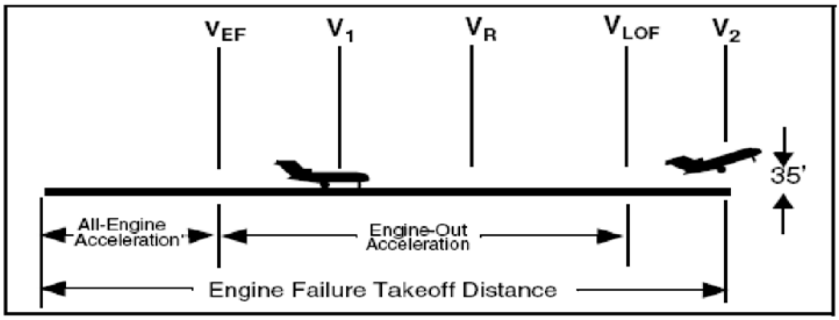
Engine Out
Engine Failure Takeoff Performance

Engine failure takeoff distance is the distance from brake release to the point where the aircraft attains a height of 35 feet, assuming an engine fails at VEF. FAR 25 requires that the length of runway plus clearway be at least equal to the engine failure takeoff distance.

Takeoff Distance with an Engine Failure



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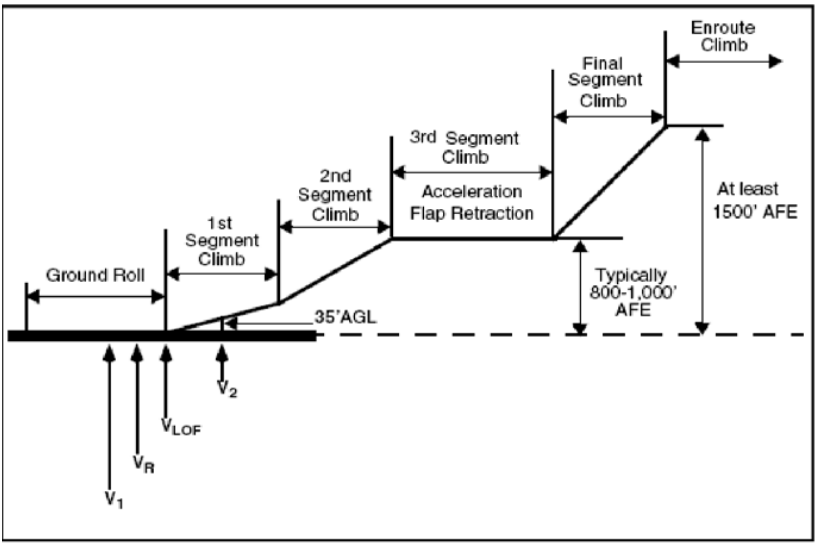
Takeoff Segments

FAR 25 specifies minimum climb gradients that must be achieved in the first, second, third and final segments.

- Delta schedules climb limit weight so that the aircraft can meet takeoff climb requirements in all climb segments. As such, climb limit weight is determined by aircraft performance and is not dependent on obstacles in the takeoff path.
- Delta schedules runway allowable weight to ensure that the net engine failure flight path will clear obstacles in the takeoff path. Regulations require that obstacles are cleared by 300 feet horizontally (200 feet within airport boundary) or by 35 feet vertically.



Basic Dispatch

Begins at VLOF and ends when the landing gear is fully retracted.

Second Segment Climb

Begins when the landing gear is fully retracted and ends at the altitude chosen for the start of flap retraction. Delta calls this altitude “clean-up altitude.” The minimum speed to be used during the second segment is V2. For a two-engine aircraft, a 2.4 percent climb gradient is required.

Third Segment Climb

The aircraft is accelerating during flap retraction and should be in level flight. A minimum acceleration capability is imposed by FAR 25.

Final Segment Climb

From clean-up altitude to a minimum of 1500 feet AFE.

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Departure Procedures (DPs)

This section describes how engine-out climb performance affects DPs and Delta special procedures. DPs may be referred to as SIDs or IFR departures in some documents.

Profile Construction

There is no significant climb performance difference between an obstacle DP or a DP used for ATC purposes.

- A DP may be used to simplify ATC clearance delivery procedures. It may also be used to assist the pilot conducting IFR flight in avoiding obstacles during climbout to a MEA or it may be used for traffic separation.
- An obstacle DP is used primarily when an obstacle analysis reveals obstacles that penetrate the FAR required climb gradient on departure.
  - Obstacle clearance is based on the aircraft climbing at least 200 feet per nautical mile, crossing the end of the runway at least 35 feet AGL, and climbing to 400 feet above airport elevation before turning, unless otherwise specified in the procedure.
  - A slope of 152 feet per nautical mile, starting no higher than 35 feet above departure end of the runway, is assessed for obstacles.
  - A minimum vertical obstacle clearance of 48 feet per nautical mile is assured provided the aircraft climbs at the minimum climb gradient. Unless published higher on the appropriate departure chart, the minimum climb radiant is 200 feet per nautical mile.

Note: This procedure can require a ceiling and visibility to allow the obstacles to be seen and avoided, a climb gradient greater than 200 feet per nautical mile, detailed flight maneuvers, or any combination of the above.

Performance Considerations

There are many differences between Terminal Instrument Procedures (TERPS) and engine-out criteria, including the lateral and vertical obstacle clearance requirements.

- Engine-out procedures do not need to meet TERPS requirements.
- TERPS climb gradient requirements do not necessarily ensure that engine-out obstacle clearance requirements are met.
- DPs allow relatively low minimums but may be predicated on climb gradients which may not be attainable after an engine failure.

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Delta Special Departure Procedures

Delta is responsible for determining that all departures maintain the obstacle clearance required with an engine failure in accordance with FARs.

Maximizing Takeoff Weight

The most common procedure to maximize takeoff weight when significant obstacles are present along the normal departure route is to use a special departure routing in the event of an engine failure on takeoff.

- Obstacles along the engine failure departure routing are used to determine the maximum allowable takeoff weight for that runway.
- If possible, the engine-out departure routing is designed to coincide with the flight path for normal departures.

Determining Takeoff Weight

When determining the limiting takeoff weight, the obstacle analysis is carried out to the end of the takeoff segment. For the purpose of obstacle analysis, the end of the takeoff segment occurs when the aircraft is at:

- Minimum crossing altitude (MCA) at a fix, or
- Minimum enroute altitude (MEA) for a route to the intended destination, or
- Minimum vectoring altitude (MVA), or
- A fix and altitude from which an approach may be initiated to the departure airport or departure alternate.

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Airport Specific Departure Procedure

Delta provides special departure procedures for those stations which require additional guidance regarding the engine-out departure. The regulations require that the net takeoff flight path clears all obstacles by 35 feet vertically or 200 feet laterally inside the airport boundary or 300 feet laterally outside the airport boundary.

To ensure the required lateral clearance, Delta must account for factors that could cause a difference between the intended and actual flight paths and between their corresponding ground tracks.

For example, two considerations are the loss of climb capability during turns in holding patterns or other maneuvers which may be necessary to reach en route altitudes and aircraft speeds and their effect on turn radius during determination of flight paths.

- Engine-out bank angle must also be considered in procedure development. FAR 121.189 assumes an engine-out bank angle limited to 15 degrees at V2 and the AFM generally provides a climb gradient decrement for a 15 degree bank. For angles less than 15 degrees, a proportionate amount of the 15 degree value may be applied, unless the manufacturer or AFM has provided other data.
- Obstacle clearance at certain airports can be enhanced by the use of bank angles greater than 15 degrees.
  - If bank angles of more than 15 degrees are used, V2 speeds may have to be increased to provide an equivalent level of stall margin protection and adequate controllability (VMCA).
  - Bank angles up to 25 degrees engine-out are acceptable, provided that adequate controllability and equivalent stall margins are maintained and climb gradient decrements are applied.
  - Bank angles over 25 degrees may be appropriate in certain circumstances but require specific evaluation and FAA approval.
- FARs do not specifically require an obstacle clearance analysis for engine-out missed approaches or rejected landings since this would involve multiple failures. It is, however, appropriate to provide information to the flight crews on the safest way to perform such a maneuver should it be required. The operator may develop the methods and criteria for the analysis of engine-out missed approach procedures which best reflect that operator's operational procedures.
- Generally, published missed approach procedures provide adequate terrain clearance; however, further analysis may be required if:
  - Published missed approach has a climb gradient requirement, or
  - Departure procedure for the runway has a published minimum climb gradient, or
  - A special engine-out takeoff procedure is required. A distinction needs to be made between a missed approach and a rejected landing.

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- An engine-out missed approach from the minimum descent altitude (MDA), decision height (DH), or above, can frequently be flown following the published missed approach procedure.
- When rejecting a landing past the published missed approach point pilots must be aware of any published special departure procedure for terrain clearance. Consult the applicable Company pages for the runway in use.

Go-around, missed approach, and rejected landing have been mistakenly interchanged. A brief definition of each follows:

- **Go-around** is a generic term used to describe pilot actions and configuration/power changes applied when an approach is discontinued. For a visual approach or VFR, unless otherwise directed, over-fly the runway, climb to pattern altitude, and enter crosswind leg.
- **Missed approach** is a published procedure beginning at the missed approach point (MAP).
- **Rejected landing** is a go-around initiated past a published missed approach point.

WARNING: Terrain clearance is guaranteed only when executing a published missed approach procedure at the missed approach point. A rejected landing past the missed approach point may require some other choice, such as a departure procedure.

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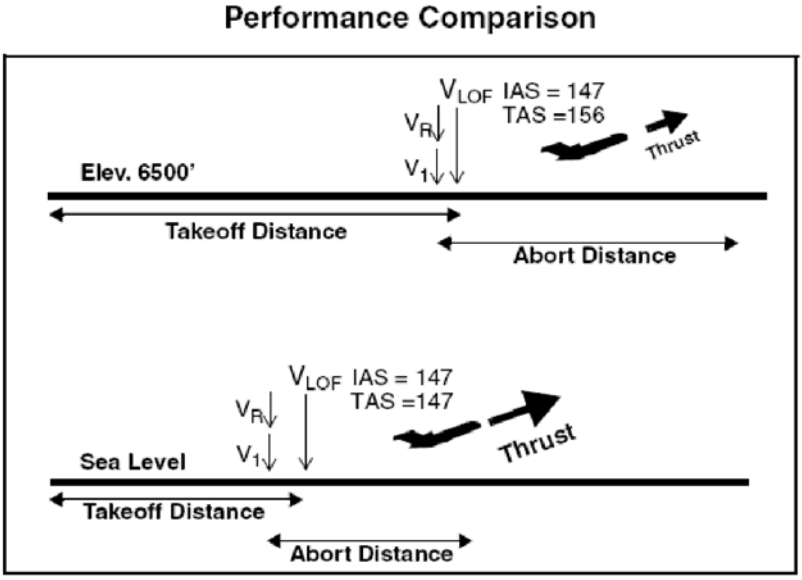
High Elevation Considerations

Aircraft Performance Characteristics

Two principles combine to degrade jet aircraft performance at high elevation.

- Available thrust is reduced.
- True air speed (TAS) is higher for a given indicated air speed (IAS).

Overall performance degradation is obvious for runways of identical length and ambient conditions except for a significant pressure altitude difference.



Significant effects are summarized as follows:

- Takeoff distance required is increased. Although IAS remains unchanged for the same gross weight and drag, ground speed is higher.
- Stopping distance required is increased. Landing distance increases approximately 3.5 percent for every 1000 feet of elevation above sea level.
- Distance required to reject takeoff is increased.
- Turning radius is increased.
- Higher RPM setting is required to maintain same thrust.
  - Higher RPM required on final approach for same descent rate.
  - Go-around capability (or excess thrust) is reduced.

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Stopping Dynamics

The critical physical dynamics of high elevation stopping are considered within takeoff and landing limitations. The greater the pressure altitude (or greater the true airspeed for an IAS), the greater the stopping distance required. This reduces takeoff and landing performance limit weights at high elevation airports.

- High elevation takeoffs are usually limited by the climb limit weight. Whenever the runway allowable takeoff weight (RATOW) is larger than the climb limit weight, an excess of runway for a rejected takeoff is available, but no extra comfort level should be assumed.
- Landing climb performance limitations at high elevation airports, as elsewhere, are dependent upon the ability of an aircraft to meet engine-out rejected landing parameters. It is possible to dispatch an aircraft to a high elevation station contingent upon a reduced flap landing. When this occurs, a notation indicating the landing flaps to be used will appear on the AWABS. The “performance cushion” is generally small and correct landing speed, touchdown point and braking are necessary to ensure a safe landing.
- Higher landing TAS is fully appreciated by crews experienced with high elevation flying. Kinetic energy can be appreciated by understanding the formula: KE = 1/2 MV2 where M represents mass (or weight) and V represents velocity or ground speed. A change in the speed has a greater impact on kinetic energy than a proportional change in weight.

Note: At an elevation of 5000 feet, kinetic energy is approximately 16 percent greater for the same landing speed range compared to an aircraft of the same weight at sea level.

- A decision for a high speed rejected takeoff maneuver is protected to V1, so long as the anomaly is indeed loss of an engine, it is recognized prior to V1 and full braking is applied by V1. Crews tempted to reject a takeoff for non-airworthy faults should be conscious of the relatively greater kinetic energy to be arrested when operating at higher elevations. Likewise, crews should have confidence in the safeguards provided within the limitations and configurations used to maximize payloads to and from high elevation stations.

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Performance Considerations

Note: All numerical comparisons are for example only and do not replace the actual values found in the aircraft manuals.

Factors Affecting Takeoff Performance

Dynamic pressure is measured in the flight deck by KIAS. An airplane in a set configuration requires a certain dynamic pressure for takeoff which provides lift equal to weight, referred to as takeoff speed. It is invariant with altitude, temperature, wind, etc. It does vary directly with gross weight.

Altitude

Aircraft operated from increased altitudes require increased takeoff distances. The same dynamic pressure, therefore the same KIAS, is required as at sea level. But due to reduced air density, a greater actual velocity (true airspeed) is necessary to provide that pressure. At 6500 feet MSL a typical takeoff true airspeed is increased about 10 knots over that at sea level. Depending on the specific engines, less thrust may be available at higher elevations for acceleration.

Slope

The effect of runway slope is due to the component of weight along the inclined path. It's effect is usually minor. A one percent slope may cause a two to four percent change in takeoff distance. Aircraft with high thrust-to-weight ratios are least affected.

Weight

Aircraft acceleration also varies directly with gross weight. A heavy aircraft accelerates slower and must be accelerated to a higher velocity for takeoff, lengthening the takeoff roll. A 10 percent increase in gross weight typically increases takeoff distance by 20 percent.

Wind

Wind influences takeoff distance by affecting the ground velocity required for takeoff. A wind parallel to the runway which is 10 percent of the takeoff speed will affect takeoff distance by about 20 percent.

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Factors Affecting Landing Performance

Any factor that alters landing velocity or deceleration will affect landing distance. An increase in gross weight requires a greater speed to support the airplane at the landing angle of attack.

- A 20 percent increase in weight will require about a 10 percent increase in landing KIAS to support the greater weight, producing an approximate 20 percent increase in landing distance.
- Increased gross weight causes like increases in the sum of drag plus braking friction, so deceleration is essentially unaffected.

A reduction in density will increase the landing velocity at a constant KIAS, but does not alter the retarding force. The airplane lands at altitude with the same weight and dynamic pressure as at sea level; therefore, drag and braking frictions have the same values. As long as the condition is within the capability of the brakes, net retarding force is unchanged and deceleration is the same as sea level. The increase in landing distance with altitude is approximately 3.5 percent for each 1000 feet of change.

All aircraft land at a particular airspeed independent of wind. Wind changes the ground velocity at which the airplane touches down. As previously discussed, a 10 percent change in the ground velocity will produce about a 20 percent change in distance required.

While corrections are made for the effect of runway slope on landing distance they are typically small. Runway selection is usually based on wind.

Velocity on the ground determines landing roll if braking is constant. Pilot technique can impact the velocity. Pilots also control braking (to the limits of the aircraft) and touchdown point. Fast or long touchdowns or improper braking technique may add up to a landing roll greater than the distance available, even if all the book numbers add up.

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Climb Performance

Best Angle of Climb Speed

The best angle of climb occurs at a particular KIAS where thrust required for flight is at a minimum. The maximum steady state climb angle can be attained at this speed, with the angle increasing directly with the amount of thrust available over that required. Any factor that increases thrust required, such as banking the aircraft, or that reduces the thrust available, such as an increase in altitude, will reduce the angle. Of course, the actual angle in relation to the earth varies with winds. Best angle of climb speeds are lower than those for best rate of climb or computed enroute climb speeds based on costs. Best angle of climb speeds are useful when obstacles exist in the departure path and/or where a large radius of turn could pose problems. In that environment, pilots should consider use of best angle of climb speed to the appropriate minimum altitude (MEA, MVA, MSA, etc.).

Best Rate of Climb Speed

The rate of climb, vertical velocity, depends on the flight speed and the inclination of the flight path. The rate of climb is the vertical component of the flight path velocity. The maximum rate of climb occurs where there exists the greatest difference between power available and power required. Jet aircraft have a linear variation of power available with speed, so the speed for maximum rate of climb is usually well above that for best angle. An increase in weight will reduce the maximum rate of climb, but the airplane must be operated at a higher speed to achieve the smaller peak climb rate. An increase in altitude will at the same point start to lower the power available for the climb. A deterioration of climb performance at higher altitudes should be expected therefore. Steady state wind has no effect on rate of climb, although wind shears can dramatically alter climb rates.

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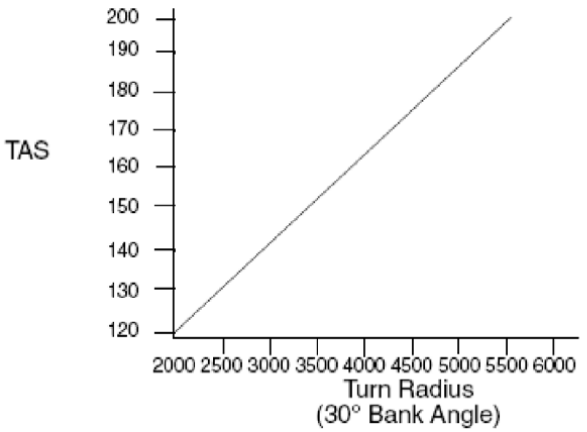
Turning Performance

A level flight coordinated turn is one in which the vertical component of lift is equal to the weight of the aircraft; no vertical acceleration takes place. As bank angle is increased, the load factor required to maintain level flight is increased from 1.0 G at 0 degrees, to 1.036 G at 15 degrees, 1.154 G at 30 degrees, and 1.414 G at 45 degrees. Induced drag also increases with bank angle, increasing the thrust or power required to maintain altitude and increasing stall speed. In a sense, aircraft performance in a turn is affected in much the same manner as an increase in gross weight. At 45 degrees, bank induced drag is increased by 100 percent.

Within the airplane's structural limitations, turning performance is determined by bank angle and velocity (true airspeed). When flown in a steady, coordinated turn at a specific bank angle and velocity, turn rate and radius are fixed and independent of aircraft.

Turns at 160 KTAS		
Bank	**Radius**	**Diameter (NM)**
30	3,952	1.3
25	4,853	1.6
20	6,269	2.1
15	8,516	2.8
10	12,941	4.3

Turn radius varies with velocity at constant angles of bank. Use the following chart to determine turn radius with 30 degree bank angles.



TAS	Radius
200	6,175
190	5,573
180	5,002
170	4,461
160	3,952
150	3,473
140	3,026
130	2,609
120	2,228

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Estimating Turn Radius

Mile Per Minute

A good estimate of turn radius at 30 degrees bank is velocity measured in miles per minute (mpm) - 2.

radius (nm) = mpm - 2

Use each unit of 60 knots TAS as 1 mpm, TAS/60 = mpm. At 180 knots TAS, aircraft velocity is approximately 3 mpm so turn radius at a constant 30 degrees bank is about 1 nm.

Mach Number

Mach number may also be employed. Use each 0.1 unit of Mach to represent 1 mpm, Mach x 10 = mpm, so at.8 Mach velocity is about 8 mpm and turn radius is approximately 6 nm.

Rate of Turn

An alternate and very useful method of estimating an aircraft's radius of turn is to consider turning performance at a constant rate of turn of 1.5 degrees per second. Use 10 percent of velocity (TAS) to figure turn radius in nm, 1.5 degrees rate of turn radius (nm) = TAS/10. A 1.5 degree per second turn at 200 TAS requires about 17 degrees of bank, at 150 TAS around 13 degrees.

Determining Lead Point

It is relatively simple to apply turn radius information when tracking toward a facility with DME, just remember to consider start range when required. It is a little more involved when flying across radials, such as during an arcing procedure. It is necessary to use the relationship that the width of a degree varies directly with distance from its origin.

- At 60 miles from the origin each degree is 1 mile wide; at 30 miles each is .5 mile; at 15 miles each is .25 mile, etc. The phrase "10 at 6, 6 at 10" is useful. At 10 miles there is 6 degrees per mile and at 6 miles there is 10 degrees per mile.
- For example, if an aircraft velocity is 210 knots TAS, using the formula TAS/60 = mpm it is traveling at 3.5 mpm, radius (nm) = mpm - 2 (30 degrees bank) so the turn radius is about 1.5 nm. If arcing at 10 miles, a turn to a radial would require about 9 degrees of lead for the example above.

Minimum Turn Radius

When a minimum radius turn is required or anticipated it is important to slow the aircraft. When the turn is initiated, use the maximum bank angle available. Winds cannot be ignored. Turns into the wind reduce turn radius in relation to terrain.

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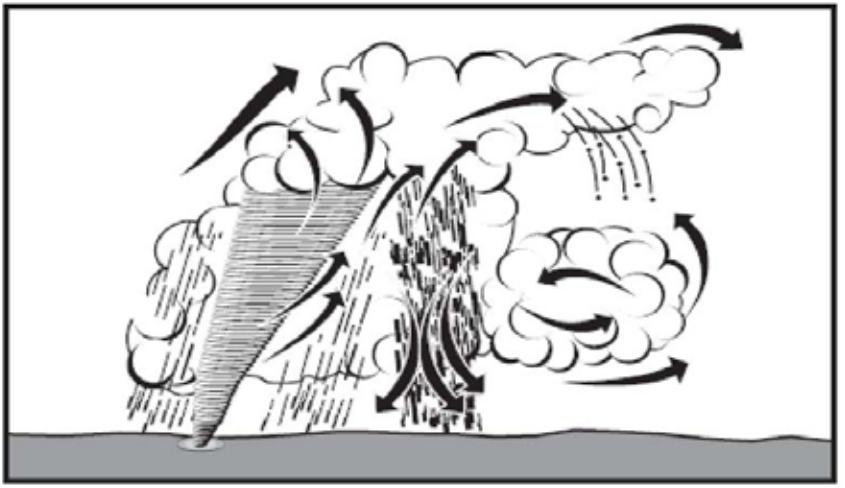
Weather Radar

Turbulence Avoidance

Research has shown that when any part of a storm reaches Level 3 strength, moderate to severe turbulence occurs with equal probability throughout all areas of the storm, including the Level 1 and 2 areas. For turbulence avoidance, all areas of a storm should be avoided when any part reaches Level 3.

The color green is often associated with safe to go or normal operation. Green does not imply go or safe in conjunction with weather radar or turbulence avoidance. In weather depiction, green simply denotes the area of Level 1 precipitation. When associated with convective weather, green areas of rain may contain violent vertical activity. The graphic below illustrates how tornadoes are most often located at the outer edge of thunderstorms in the Level 1 areas of precipitation.



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Turbulent Activity

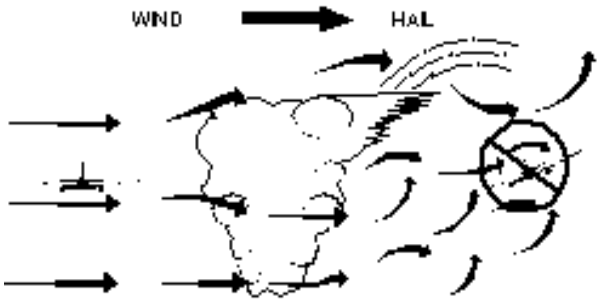
Turbulent activity occurs away from the heavy rain core. Enroute deviations should be made upwind of the storm whenever possible, especially if winds aloft are strong. Deviating downwind greatly increases the chance of encountering hail and turbulence. Turbulence can be expected to exist downwind of the storm 1nm for every knot of windspeed at flight altitude. The storm acts as an obstruction to the wind, creating turbulent eddies downwind of the storm.

To detect turbulence select the TURB mode to identify areas of horizontal movement of precipitation, which can be a good indication of turbulence.

- Turbulence will be displayed in magenta, overlaying the weather display.
- TURB mode will not detect clear air turbulence.
- Turbulence detection is limited to 40 nm.

Turbulence detection can be useful in identifying areas of turbulence, particularly in light rain areas. Some storm targets may display little or no turbulence, but that does not mean it is safe to penetrate. An absence of indicated turbulence does not justify penetrating a weather area that by other indications is hazardous.

The graphic below illustrates how enroute deviations should be made upwind of the storm and the turbulence that can be encountered downwind of the storm.



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Windshear Avoidance

Airborne radar cannot detect microbursts. However, microbursts are a product of convective cells, so airborne radar should be one of several factors considered.

Wet Microburst Environment

Wet microbursts are associated with extremely high rain rates.

- Be alert for signs of attenuation, such as crescent shaped returns or radar shadows.
- Strong returns at mid to upper levels of weather are signs of hazardous convective activity.
- Microburst producing storm cells can be small in diameter, so use short ranges when evaluating nearby cells.

Dry Microburst Environment

Dry microbursts can be produced by very light rain cells.

- Level 1 returns can produce severe microbursts.
- Dry microbursts are produced by high based virga activity.
  - Use UP TILT to direct the beam will above the flight path.
  - When evaluating the departure path before takeoff, full UP TILT may be inadequate to detect high based showers within 10 nm.
- TURB mode may be useful. Turbulence indicated in light returns is evidence of strong activity.
- Cells may be small. Use short ranges when evaluating nearby targets.

Radar has inherent limitations when evaluating nearby and or intense weather areas. Consider all factors, including visual cues, in making windshear avoidance decisions.

Predictive Windshear Alerts

The weather radar uses radar imaging to detect disturbed air prior to entering a windshear. Weather radar:

- Provides windshear alerts for windshear events containing some level of moisture or particulate matter.
- Detects microbursts and other windshear with similar characteristics.
- Does not provide alerting for all types of windshear.

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Hydroplaning

Scientific reports on hydroplaning cite water depth, speed, tire tread depth, runway surface texture, tire inflation pressure, effective weight, and landing gear arrangement as contributing factors.

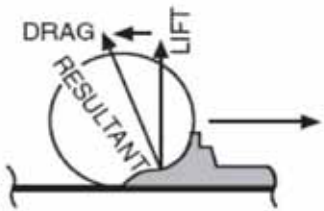
Experts generally agree that there are three types of hydroplaning: dynamic (or hydrodynamic), viscous, and steam (or reverted rubber). It is to be noted that these may be indistinguishable from the flight deck. All three types can seriously degrade the braking effectiveness and directional capability of the aircraft tires.

Dynamic Hydroplaning

This type of hydroplaning is a function of high speeds and can occur only when the runway surface is critically flooded. The critical depth of water (or slush) can vary from 0.1 to 0.4 inches, depending on tire and surface condition.

In the case where an aircraft is accelerating on a water-covered runway, partial hydroplaning begins as the moving tires contact and displace the stationary water. The resulting change in momentum of the water creates hydrodynamic pressures that react on the runway and tire surfaces.

The resultant force forms a fluid "wedge" which, to some degree, separates the tire from the runway and decreases the footprint area available for braking action. At some higher speed the hydrodynamic lift developed under the tire equals that part of the aircraft weight being supported by the tire, so that the tire is lifted completely off the runway surface.



The critical ground speed at which the latter occurs is termed the "tire hydroplaning speed" (VP). Partial hydroplaning is occurring at speeds below VP, total hydroplaning at speeds at or above VP.

Additionally, as the tire accelerates, the center of hydrodynamic pressure shifts increasingly forward of the axle center line, creating a wheel spindown moment.

At the same time, the friction-induced spin-up moment is decreasing with decreased footprint area until, at some vehicle speed, the wheel will begin to slow down and stop. This can occur before hydroplaning commences and at this point the effectiveness of wheel braking is lost. The small residual footprint disappears at VP along with all tire-to-surface friction and cornering effects.

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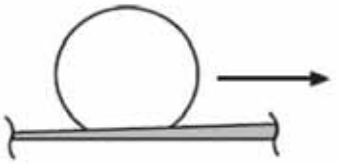
Of additional concern in the takeoff regime is the effect of fluid displacement drag. Where a runway is heavily flooded with water or slush, this drag factor increases with speed, peaking near VP. This can result in greatly increased takeoff distances, and is the main reason for the "1/2 inch rule."

Some discussion is in order on the subject of total hydroplaning speed (VP), which is defined as the speed at which the tire is lifted completely off the surface. The most preponderant opinion is that this speed in knots may be approximately by the formula $VP = 9\sqrt{p}$, Where p is the tire inflation pressure. If this thesis is accepted as true, then most aircraft will find themselves in a total hydroplaning condition at the high-speed end of the takeoff and landing operations (if fluid is above the critical depth). Other respected opinion holds that this formula is oversimplified and that the total hydroplaning condition is never reached within the normal groundspeed envelope. The argument is academic, however, since effective footprint area will be minimal at speeds approaching Vp on flooded runways.

For the decelerating or landing condition where hydroplaning occurs, the effects will be the same as in acceleration, but in inverse order. Experiments have shown that, in deceleration from a hydroplaning condition, a tire will spin up at a slower ground speed than that required for spin-down in an accelerating condition. This suggests that dynamic hydroplaning may be more serious for landings and aborted takeoffs than for takeoffs because of the greater speed range of potential exposure.



The question may arise whether fluid displacement drag may help in slowing an aircraft in hydroplaning conditions. This parameter will be helpful at speeds close to VP, but the effect drops sharply at higher or lower speeds.

It should be noted that, while hydroplaning is the most serious condition, some degradation in braking and cornering effectiveness begins with partial hydroplaning at speeds well below VP. From this point, adverse effects increase as a function of the square of the ground speed.

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Viscous Hydroplaning

Even slight amounts of precipitation, such as heavy dew, can result in this type of hydroplaning. Loss of traction can occur at relatively low speeds because of the inability of the tires to penetrate a very thin but tenacious fluid film on a smooth pavement surface. The requirements for viscous hydroplaning are:

- A very smooth or smooth-acting runway surface.
- A thin film of water or other contaminant; film thickness required is estimated to be less than 0.01 inches.

Exposure to viscous hydroplaning is thus greatest on an abnormally smooth runway, or one that has become heavily coated with rubber from landings and wheel spin-up. Complete separation of tire and surface can occur at groundspeeds at least 35 percent less than the speeds required for total dynamic hydroplaning. The effects, however, can be equally hazardous.

Steam Hydroplaning (Reverted Rubber)

This type of hydroplaning is associated with wet runway conditions where the tire is allowed to remain locked up for a period of time. The longer the tire remains stationary, the more total heat is dissipated in the footprint area, converting the water to superheated steam. Steam pressures then lift the tire from the runway surface.

Temperatures up to 500°F can be generated in this process, which tends to explain the observed damage to tire structure. The tire shows a patch of rubber that looks like it has been heated to the melting point and then reverted to the uncured state: hence the term “reverted rubber.” It has been suggested that this melted rubber may form a seal, trapping the steam in the footprint area, while some sources maintain that steam can be generated, without a seal, at a rate sufficient to sustain hydroplaning. The high-pressure steam also tends to explain the white (steam-cleaned) marks on the pavement, characteristic of steam hydroplaning.

Since one of the requirements of steam hydroplaning is a high temperature in the footprint, this is more likely to occur on damp to moderately wet pavement rather than in heavy water where a lower tire friction is experienced. In this process, friction coefficients are similar to total hydroplaning conditions. Most important is the fact that steam effect can persist to extremely low groundspeeds, measured in some cases to be below 20 knots.

The key to preventive measures in this case is the avoidance of wheel lockup and the resulting skid. It follows, therefore, that steam hydroplaning cannot occur if antiskid devices are operating properly and there is no residual drag in wheel bearings or brakes.

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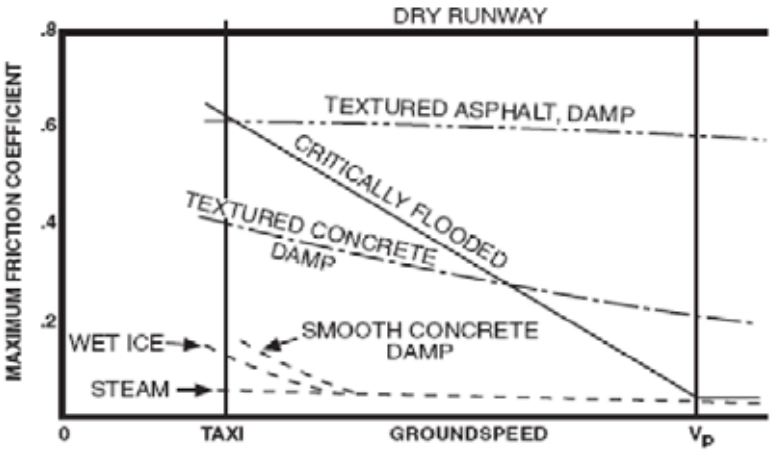

Controllable Physical Factors

Having discussed the conditions which cause hydroplaning, we may now describe measures to control the conditions.

Tires

Inflation Pressure

Considering the formula for total dynamic hydroplaning VP = 9, it would appear that an infinitely high inflation pressure could remove the threat of hydroplaning in the normal speed envelope. There is, though, only a small practical range of inflation pressures available.

Tread Design

Adequate tread designs tend to increase the groundspeed required for hydroplaning, while also increasing the minimum fluid depth required. Radically grooved tires tend to improve substantially the traction on a critically flooded surface, even when the fluid depth is greater than the tire tread depth. This design provides a low-pressure escape route for water and steam. Slippery runway performance is a prime consideration in Delta's selection of tread design.

Landing Gear

In tandem-wheel landing gear arrangements, the patch clearing action of the front tire tends to reduce the fluid depth for the rear tire, increasing its traction capabilities.

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Runways

Pavement Crown

A good crown can inhibit hydroplaning conditions by draining water off rapidly. Slush conditions are not as readily drained.

Surface Texture

A rough or open textured surface can inhibit viscous hydroplaning by puncturing the thin fluid film with sharp asperities. It may also increase the minimum fluid depth for dynamic hydroplaning.

Pavement Grooves

Lateral grooving of runways is believed to be the most effective physical means of avoiding hydroplaning conditions. The pumping action of tires and grooves removes fluid rapidly from the footprint area. The grooves may also suppress formation of a viscous film, and the sharp edges may skim off melted rubber.

Flight Deck Considerations and Techniques

A pilot's best weapons against the problem of slippery runways are the knowledge of weather, runway conditions and the capability of planning ahead.

Weather

Snow, slush, or ice will create hazards. Heavy rain showers or continuous rain should raise the question of critically flooded runways. A heavy dew or drizzle on a smooth runway creates ideal conditions for viscous hydroplaning.

Runway Conditions

Smooth runways, or runways with heavy rubber deposits should be treated as very slippery under any moisture conditions. Care should be exercised when turning or taxiing on areas of rubber deposits, as near the ends of a runway. A runway with heavy puddling at the rollout end will not be as hazardous as one with standing water on the approach end.

Technique

If serious slippery runway conditions are known to exist, holding to allow water drainoff or diversion to an acceptable alternate should be considered. If a landing must be made on a very wet or slippery runway, appropriate operational techniques should be employed.

- Use minimum safe touchdown speed.
- Make early runway contact and early nosewheel contact to get maximum directional capability. A firm landing is better than a "grease job," which may induce hydroplaning in marginal conditions.

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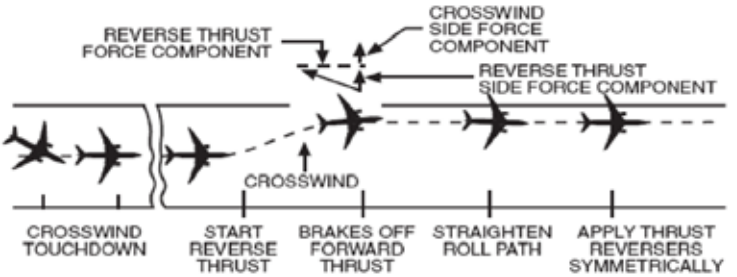
- Make early use of spoilers for better wheel spin-up acceleration and to remove lift from the wings.
- Make early use of maximum allowable reverse thrust, which is most effective at the higher speeds.
- Use autobrakes if installed.
- Make early use of wheel brakes, applied at a smooth, steady rate up to maximum braking. Do not “jump” on brakes.
- Land on centerline and track straight down the runway.

Caution should be used to avoid asymmetric application of reverse thrust or brakes with the obvious directional hazards.

Since VP is a function of groundspeed, a landing directly into the wind will decrease the exposure to hydroplaning. The worst landing condition is one where slippery runway conditions prevail with a crosswind. Besides the hazard of the crosswind side force component, there is the side force component of reverse thrust, which will compound the wind drift if the airplane is allowed to weathercock. The addition of these two forces may cause an aircraft to drift off the side of the runway under low friction conditions. Preventive measures can lengthen landing distance by causing less than optimum handling of reverse thrust. Also, a crosswind blowing up the transverse slope of a runway could create a lateral difference in water depth, possibly resulting in hydroplaning on one side and, thus, asymmetric directional control.

The airplane centerline should be aligned with the runway at touchdown (wing-down method) and initial directional control maintained aerodynamically. If the airplane weathercocks and drifts sideways during reversing, return all engines to low power forward thrust, straighten aircraft path, then resume reverse thrust.



It has been shown that any runway other than a dry runway can cause loss of traction through a wide range of speeds. General considerations and techniques have been reviewed, with emphasis on the anticipation of conditions and planning the proper action.

For maximum crosswind limits on a contaminated runway, refer to Vol. 1, SP.16, Adverse Weather.

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Delta Maneuver Training

The following information is compiled from Boeing's Upset Recovery Training Aid (September 1998) and Boeing Flight Operations Technical Bulletin (May 2002). This information is provided so pilots may better understand the key aerodynamic and structural issues concerning maneuver of transport category aircraft.

Maneuver training is integrated throughout initial qualification (IQ) training on all fleets at Delta. Specific elements include stall, CFIT, windshear and upset recovery training. Each element likewise supports core objectives, which are:

- Recognition to avoid or recognition to recover
- Protect from a stall
- Orient the lift vector
- Stabilize post recovery

Aerodynamic Aspects of Maneuver

There are three sources of energy available to the pilot:

- Kinetic energy (speed)
- Potential energy (altitude)
- Chemical energy (fuel)

The sum of all energy sources is defined as the "energy state" of the aircraft. It is important to note that only kinetic energy can be used to generate aerodynamic forces to maneuver the aircraft.

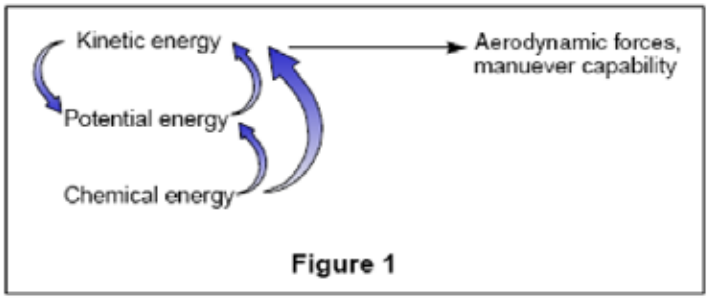

Figure 1

Understanding these energy relationships is fundamental to "energy situational awareness." Ultimately, your objective is to manage energy in a way so that:

- Kinetic energy stays between the limits (stall and placards),
- Potential energy remains within limits (terrain to buffet altitude), and
- Chemical energy remains present (above fuel exhaustion).

Only within these parameters will you be able to generate the aerodynamic forces necessary to maneuver an aircraft to return it to normal flight.

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Flight Dynamics

Flight Path Control

In the simplest sense, the pilot only controls the orientation and magnitude of the forces acting on the aircraft, which in turn define the flight path angle of the aircraft.

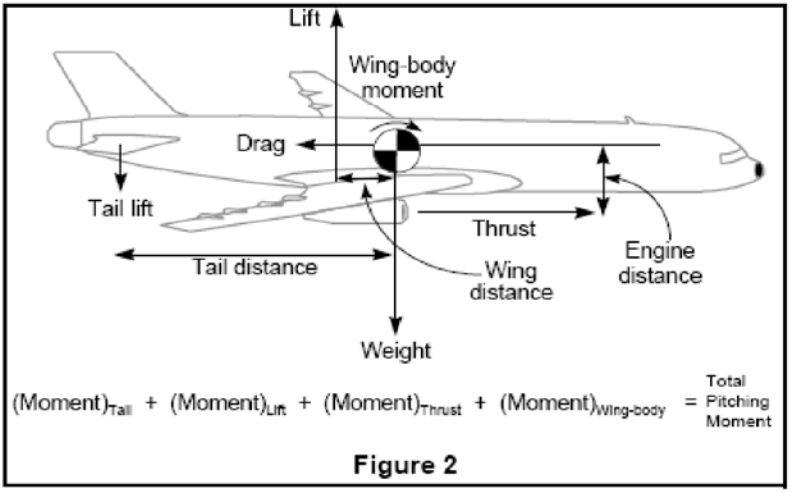

Figure 2

It is control of the flight path angle (or vector) that is critical to an aircraft during dynamic maneuver.

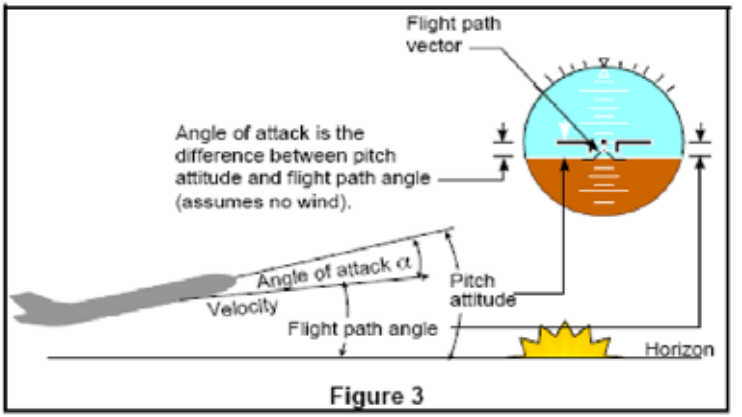

Figure 3

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Load Factor

Load factor describes the accelerations being experienced by the aircraft. Load factors apply to any of the three axis of the aircraft; however, we are mainly interested in load factors (or G loading) along the vertical axis. It is along this axis that the lift on the wing is oriented and by which we control the flight path angle of the aircraft. Remember, the aircraft is acceleration limited. Transport category aircraft are limited to 2.5 Gs in a clean configuration and 2.0 Gs with any high lift devices extended.

The issue is two-fold:

- Keep the lift vector on the aircraft pointed up, and
- Manage the energy state in a way that generates adequate force to produce the full G capability for the aircraft configuration.

This idea is best captured in a classic speed vs. load factor diagram for a typical swept wing aircraft.

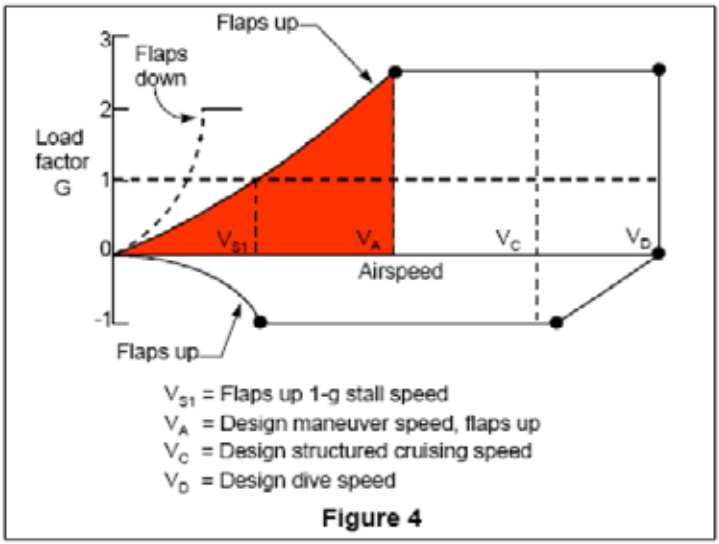

Figure 4

It is precisely in the shaded area along the 1G line that energy situational awareness must be most focused. Within this area of the flight envelope your recognition and response to an upset must be both timely and correct.

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ALPHA Factor

The wings of modern transport aircraft are designed to produce lift efficiently. The lift force, in pounds, generated by the wing is a direct function of angle of attack (AOA), or Alpha. While the pilot does have limited control of airspeed in a decreasing energy state situation, lift is primarily controlled by AOA.

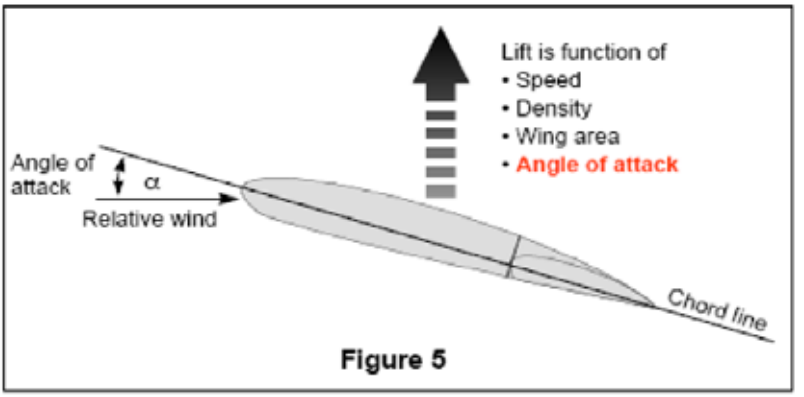

Figure 5

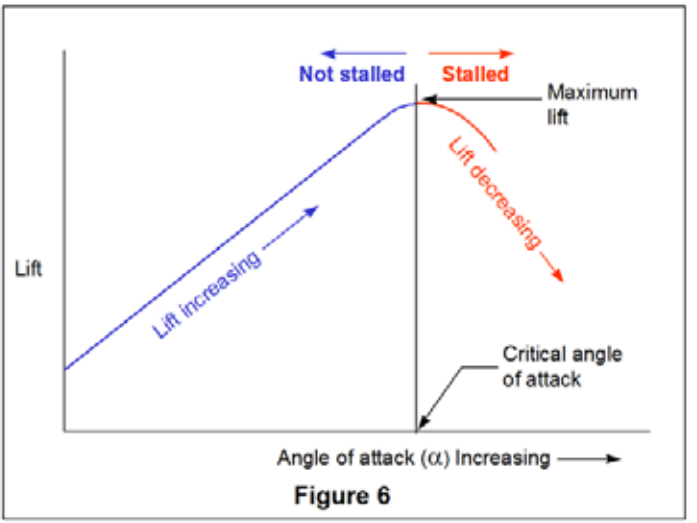

Figure 6

As indicated in the figure above, there is a linear increase in lift with increasing AOA up to the point of maximum lift. Beyond the critical AOA, lift decreases as the flow over the wing breaks down and the surface becomes stalled. It is the stalled condition which you must learn to recognize and recover from.

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Stalled Condition

A stall is characterized by one of, or a combination of, the following:

- Buffeting, which could be heavy,
- Lack of pitch authority,
- Lack of roll control, and/or
- Inability to arrest decent rate.

If the critical angle of attack is exceeded, the wing surface will stall and lift will decrease instead of increasing. This is true regardless of aircraft speed or attitude.

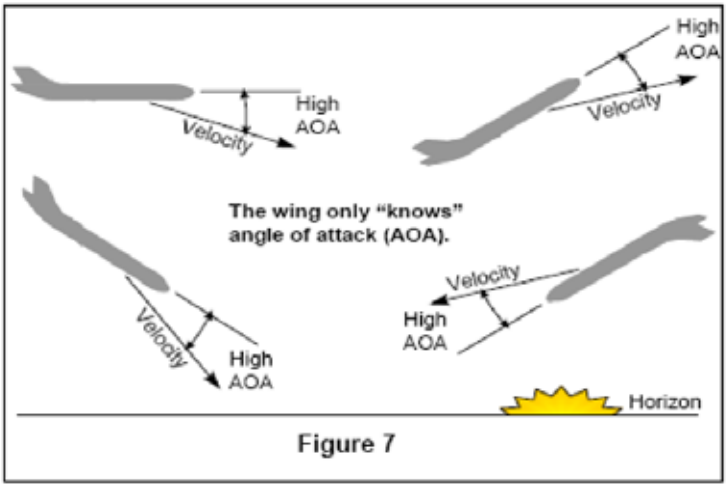

Figure 7

Note: You cannot recover an aircraft while it is stalled; you must first break the stall.

The stall speed for any aircraft is defined by the following conditions:

- Trim at 1.3 VS
- Forward CG
- Low altitude
- Deceleration rate of 1 knot/second
- Wings level
- Approximately 1G flight

In conditions other than these, the "speed at stall" is not the same as the "stall speed." Aerodynamic stall depends only on AOA and has a specific relationship to the "stall speed" only under the conditions listed above.

Note: Most upsets are quite dynamic in nature and involve elevated load factors and large speed rate changes.

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Pilots should not expect the aircraft to remain unstalled just because the indicated airspeed is higher than AFM chart speeds because the conditions may be very different. In all cases, respect the stick shaker by unloading the aircraft (reduce AOA) if a stall is encountered.

It is possible for an aircraft to be flown below the defined "stall speed." In this low energy environment the trajectory will be largely ballistic and altitude will and must be traded to generate airspeed to produce sufficient lift for 1G flight. For this reason, at low airspeed it is important to reduce the AOA, and to use all aerodynamic controls available to orient the lift so a full recovery can be made when sufficient airspeed exists.

Lateral Control

From a flight dynamic point of view, the best use of lateral control in maneuvering the aircraft is using available energy to orient the lift vector to oppose gravity. Ailerons and spoilers normally generate sufficient force for lateral maneuver. As the energy state of the aircraft decreases and AOA increases, these devices can and will lose their effectiveness. Because of this decrease in effectiveness, full lateral control inputs, ailerons and spoilers, may be necessary to maintain or regain wings level attitude after an upset.

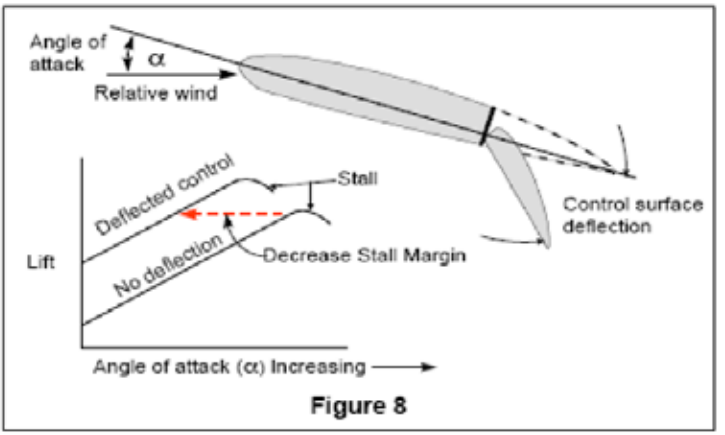

Figure 8

Note how the deflected aileron actually decreases the stall margin at high AOAs in the figure above. Likewise, spoilers, which derive lateral control by "spoiling" lift locally on a wing, are very ineffective on a stalled wing (the flow is already separated) or on a wing producing very little lift (an unloaded wing). Thus, the need for large control inputs.

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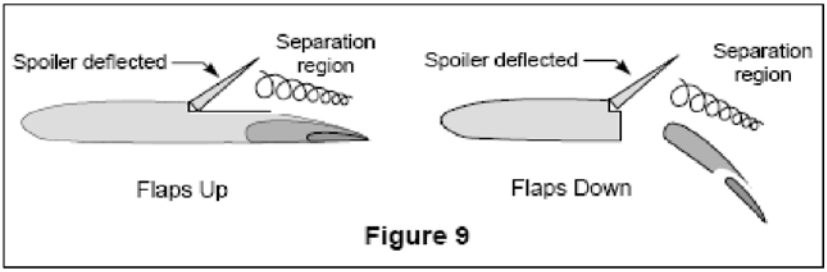

Figure 9

The rudder may also be used for lateral control, especially at higher AOAs, but must be used with caution.

CAUTION: Rudder is never the preferred initial response to induce a roll in a transport category aircraft.

Only under an extreme condition such as loss of a flap, midair collision, or when an aircraft has pitched to a very high pitch attitude and a pushover or thrust change has already been unsuccessful should careful rudder input be considered. Rudder input should be used in the direction of the desired roll to induce a rolling maneuver to start the nose down or to provide the desired bank angle. A rudder is never the preferred initial response for events such as a wake vortex encounter, windshear encounter or to reduce bank angle preceding an imminent stall recovery.

Rudder is a powerful aerodynamic tool capable of producing both yawing and rolling moments. The rudder is sized to control yawing moments for crosswind takeoffs and landings as well as adverse yaw generated by loss of engine thrust down to very low speeds. If, however, large rudder inputs are used in a symmetrical condition (i.e., no engine failure or crosswind) the rudder can produce large yawing moments resulting in very large sideslip angles and large structural loads.

Boeing aircraft have demonstrated entry and recovery from full stalls without the need for rudder. In fact, the use of rudder beyond its intended use during engine out situations or in a crosswind takeoff/landing is almost never indicated.

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Wing Dihedral and Sideslip

Dihedral refers to the positive angle between the center of the wing and the lateral axis of the aircraft.

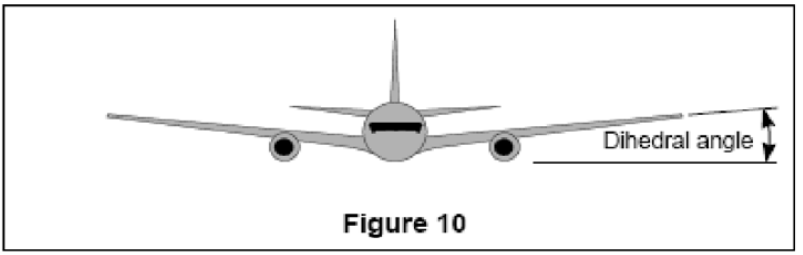

Figure 10

Wing dihedral contributes to lateral stability. Because dihedral has such a profound impact on aircraft stability, it is often used as a common term to describe other aircraft components or geometries that have a similar effect. Wing sweep is a common geometric characteristic of jet aircraft that contributes to dihedral effect. The rudder also contributes powerfully to lateral stability and control, but its use also introduces sideslip, which in turn will induce a rolling moment on the aircraft. By definition, sideslip is the angle between the longitudinal axis and the relative wind.

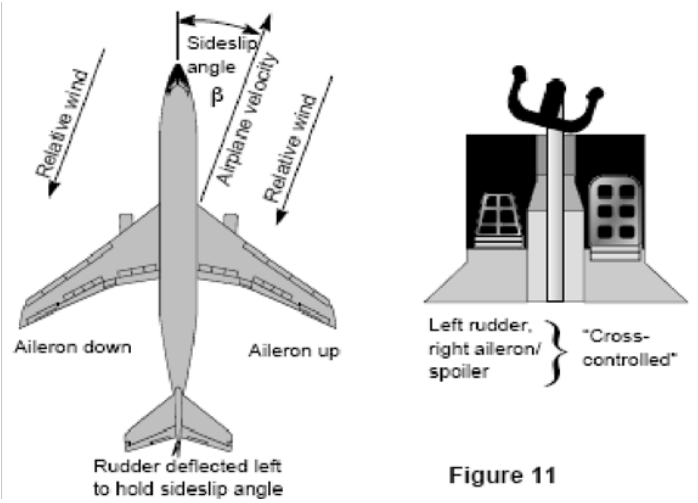

Figure 11

Sideslip can affect motion in all three axes, generating rolling as well as yawing motion. Roll coupling due to rudder induced sideslip is a common characteristic of swept wing aircraft with dihedral, especially at high AOAs and low energy states. Because of this, the rudder must be used with caution.

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CAUTION: Too much rudder applied too quickly or held too long may result in loss of lateral and directional control. Cyclic rudder pedal inputs can result in very large amplitude sideslip oscillations as well as very large, possibly excessive airframe structural loads.

Bank Angle

The horizontal component of lift will allow the aircraft to maneuver but will also require an increase in AOA (more back pressure = more load factor) to generate the additional lift necessary to maintain level flight.

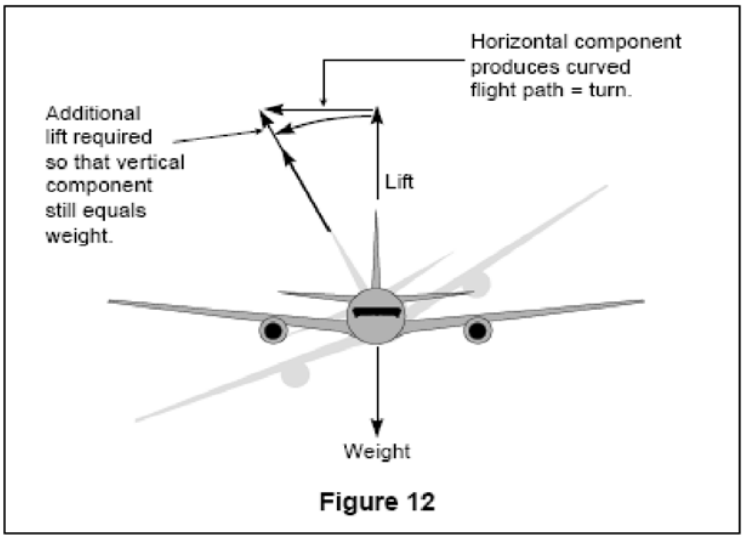

Figure 12

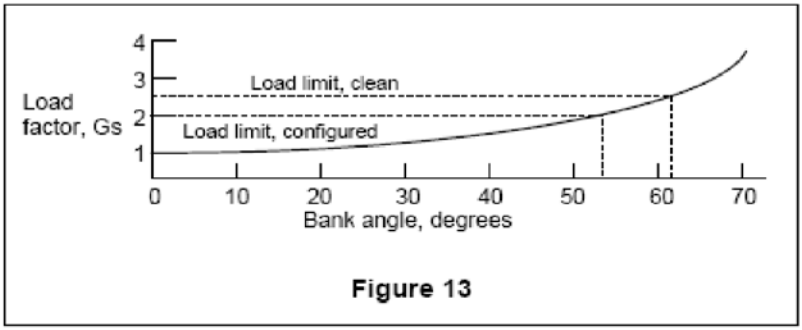

Figure 13

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Upon reaching a bank angle of 66 degrees, the load factor for sustained level flight exceeds the structural load limit for which transport category aircraft are certified. This relationship of more bank, more up elevator required, and more load factor, is very important to the mechanics of upset recovery. Since the objective is to arrest or minimize descent, an increase in pitch (back pressure), if the wings are not level, will only cause a tighter turn and, depending on the bank angle, may not help the recovery.

Note: In the context of extreme aircraft upsets, it is imperative to get the wings level before beginning any aggressive pitch maneuver.

Structural Aspects of Maneuver

Structurally, rudder should be used to induce a roll only if application of full lateral control (ailerons and spoilers) is incapable of stopping a roll rate or decreasing a bank angle.

There are several implications to the issue of full use and application of flight controls to accomplish a maneuver. Most of these are not well understood by pilots and are repeated here from a Boeing Operations Technical Bulletin.

Boeing aircraft are:

- capable of sustaining a single input to any set of control surfaces (elevators, ailerons, rudder(s)) to their maximum available authority (as limited by control surface limiters, blowdown, or control stops). These control surface inputs are to be in one axis (not in combination) and do not include control input reversal or oscillatory inputs.
- designed for full rudder input out to the maximum operating airspeed VMO/MMO and for some models to the design dive speed VD/MD.
- designed to withstand a rapid rudder input to full rudder deflection starting from a zero sideslip condition. A Safety Factor of 1.5 is then applied. This means the structure must have at least a 50% safety margin over the maximum load generated by this maneuver.
- designed to withstand, starting from a zero sideslip condition, a rapid rudder input to full deflection until the maximum sideslip angle (over yaw) is achieved. The aircraft will exceed the maximum steady state sideslip due to the dynamic response characteristics of the aircraft. A Safety Factor of 1.5 is then applied.
- designed to withstand, starting from a maximum steady heading sideslip condition, a rapid rudder return to neutral while maintaining the initial sideslip angle. A Safety Factor of 1.5 is then applied.
- equipped with vertical fins that can sustain loads if the rudder is rapidly returned to neutral from a dynamic overyaw sideslip.

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Pilots must remain aware that Boeing aircraft have been designed to structurally accommodate a rapid and immediate rudder pedal input going in one direction from zero (neutral) input to full input. Likewise, Boeing aircraft can withstand the structural loads if the rudder is rapidly returned to a neutral position from either a full dynamic or static sideslip. However, the aerodynamic necessity for such large-scale rudder inputs is almost never indicated or required!

Considered from either an aerodynamic or structural point of view, best use of the rudder would be in a manner to avoid unintended sideslip angles and the resulting (and possibly excessive) roll rates. Remember, the roll rate generated by using the rudder is proportional to the amount of sideslip, not the amount of rudder input.

Large amplitude rudder inputs can lead to abrupt roll onset and resulting large amplitude roll oscillations. The amplitude of these types of oscillations can generate loads that exceed the limit loads and possibly the ultimate loads to which the aircraft was designed. The very real possibility of significant structural damage should be obvious.

Lastly, it is important to remember that the rapid cycling of primary flight controls (also referred to as flight control reversals) from a deflection in one direction, through the neutral position, to a deflection in the opposite direction must be avoided. It is the cycling of the rudder, or any other primary flight control, that can rapidly lead to excessive structural load buildup on the associated flight surface or other areas of the aircraft such as the engine struts. In particular, sequential full or nearly full authority rudder reversals may not be within the structural design limits of the airplane, even if the airspeed is below the design maneuver speed. There are no Boeing procedures that would require this type of rudder input.

The recovery environment must take into consideration the possibility of larger than normal pitch and roll rates introduced by the amplitude of necessary aerodynamic control inputs.

- Achieving lateral directional stability, post recovery, becomes the primary focus.
- Careful judicious use of rudder must be the norm.
- Coordinated flight control inputs and coordinated flight dynamics to the maximum extent possible must be the target.
- Allowing the natural pitch and roll damping to affect recovery oscillations will prevent unnecessary or excessive cycling of primary flight controls.

Understanding dynamic maneuver of transport category aircraft is an integrated whole involving aerodynamic capabilities as well as structural limitations of the airframe. Both are important, and Delta's training will continue to emphasize the necessary skills development to counter the threats inherent to daily operations.

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Index Chapter Index

A

Acceleration to and Deceleration from VMO 7.1
Adverse Runway Conditions - Takeoff 3.9
Aerodynamic Aspects of Maneuver. 10.23
AFDS Autoland Capabilities 5.22
AFDS Faults 5.24
AFDS Guidelines. 1.24
Air Crew Human Factors. 9.1
Aircraft Performance Characteristics. 10.7
Airspeed Unreliable. 8.22
Antiskid Inoperative - Landing. 8.26
Approach Category 5.1
Approach Clearance 5.2
Automatic Flight - AFDS 1.24
Autopilot Engagement - After Takeoff. 3.20
Autospoiler/Autobrake Demonstration. 7.13
Autothrottle Use. 1.25

B

Bird Strikes 8.12
Bounced Landing Recovery 6.12

C

CAT III Operations. 5.21
Category III Operations 5.21
Center-Of-Gravity Effects on Takeoff 3.5
Circling Approach Profile. 5.44
Circling Approach 5.43
Circling Maneuver - General 5.46
Climb Constraints 4.2
Climb Modes 4.1
Climb Performance 10.11
Command Speed - Non-Normal Conditions 1.18
Command Speed 1.17

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Controllable Physical Factors 10.20
Crew Resource Management 1.1
Crew Specific Behaviors 9.12
CRM Skills 9.3
Crosswind Guidelines - Takeoff 3.6
Crosswind Landings 6.26
Crosswind Takeoff 3.6
Cruise Performance Economy 4.10

D

Damage Assessment and Aircraft Handling Evaluation 8.37
Decision Altitude or Height - DA(H) 5.19
Delta Maneuver Training 10.23
Departure Procedures (DPs) 10.3
Derated Takeoff Thrust (Fixed Derate) 3.8
Descent Constraints 4.17
Descent Path 4.17
Descent Planning 4.14
Descent Rates 4.21
Descent Speed Determination 4.17
Ditching 8.5
Dutch Roll 7.5
Dynamic Hydroplaning 10.17

E

Economy Climb Schedule - FMS Data Unavailable 4.4
Economy Climb 4.4
Emergency Descent 7.6
Engine Failure During a Reduced Thrust (ATM) Takeoff 3.34
Engine Failure Recognition - Takeoff 3.27
Engine Failure Takeoff Performance 10.1
Engine Failure versus Engine Fire After Takeoff 8.9
Engine Icing During Climb 4.4
Engine Icing During Descent 4.23
Engine Inoperative Climb 4.5
Engine Inoperative Cruise/Driftdown 4.11

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Engine Inoperative, Rudder Trim - All Instrument Approaches 5.55
Engine Out Familiarization 7.2
Engine Out Taxi. 2.10
Engine Out 10.1
Engine Tailpipe Fire 8.9
Engine Vibration 8.11
ETOPS 4.14
Evacuation. 8.14

F

Factors Affecting Landing Performance 10.10
Factors Affecting Takeoff Performance. 10.9
Fail Operational. 5.22
Fast/Slow Display Use 1.20
Fatigue 9.8
Flap Configurations for Approach and Landing. 5.4
Flap Extension. 5.4
Flap Maneuver Speeds. 1.16
Flap Retraction - One Engine Inoperative. 3.29
Flap Retraction Schedule 3.20
Flap Setting for Landing 5.4
Flaps and Landing Gear 4.22
Flaps Up Landing 8.17
Flare and Touchdown 6.8
Flight Deck Considerations and Techniques. 10.21
Flight Dynamics. 10.24
Flight in Moderate to Heavy Rain, Hail, or Sleet 1.27
Fuel Balance 8.24
Fuel for Enroute Climb 4.9
Fuel Leak. 8.25

G

Go-Around after Touchdown. 5.73
Go-Around and Missed Approach - All Engines Operating. 5.69
Go-Around and Missed Approach - All Instrument Approaches 5.67
Go-Around and Missed Approach - Engine Failure During. 5.66

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Go-Around and Missed Approach - One Engine Inoperative 5.62
Go-Around and Missed Approach Profile - All Approaches 5.67
Go/Stop Decision Near V1 . . . . . 3.15

H

High Altitude High Speed Flight 4.12
High Altitude Maneuvering, “G” Buffet 7.4
High Elevation Considerations 10.7
Holding Pattern Exit 4.25
Holding 4.24
Hydraulic System(s) Inoperative - Landing 8.26
Hydroplaning 10.17
Hydroplaning, Flight Deck Considerations and Techniques 10.21

I

ILS - One Engine Inoperative 5.55
ILS Approach - Landing Geometry 5.27
ILS Approach 1 ENG INOP FMA Progression 5.54
ILS Approach Profile - One Engine Inoperative 5.53
ILS Approach Profile 5.5
ILS Approach 5.8
ILS Autoland Approach Profile 5.12
ILS CAT III Approaches 5.17
ILS or GLS Approach 5.5
ILS Performance 5.22
ILS PRM Approach 5.25
ILS (GS Out) or LDA (without GS) or LOC or VOR Approaches 5.34
Immediate Turn after Takeoff - All Engines 3.18
Immediate Turn after Takeoff - One Engine Inoperative 3.28
Initial Climb - All Engines 3.18
Initial Climb - One Engine Inoperative 3.28
Instrument Approach Using V/S Profile 5.31
Instrument Approach Using V/S 5.41
Instrument Approaches 5.1

J

Jammed or Restricted Flight Controls 8.19

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L

Landing at the Nearest Suitable Airport 8.4
Landing Distance (Factors Affecting) 6.14
Landing Distance (Non-Normal) 6.15
Landing Flare Profile 6.10
Landing on a Flat Tire 8.27
Landing Roll 6.12
Leading Edge Flaps Transit - Landing 8.18
Liftoff - Effect of Rotation Speed and Pitch Rate 3.5
LNAV - Non-ILS Approach 5.40
LOC (BACK CRS) or NDB Approach Guide 5.36
Loss of Engine Thrust Control 8.10
Loss of Thrust on Both Engines 8.10
Low Altitude Level Off - During Climb 4.2
Low Fuel Operations In-flight 8.25
Low Visibility Takeoff 3.9

M

Mach Buffet 7.4
Mach Tuck 7.4
Maneuver Margin - Landing and Go-Around 5.3
Maneuver Margins to Stick Shaker 1.16
Manual Flight 1.25
Map Failure 1.27
Maximum Altitude - Cruise 4.7
Maximum Angle Climb 4.4
Missed Approach - Circling 5.48

N

Noise Abatement Takeoff 3.26
Non - ILS Instrument Approaches - General 5.38
Non - ILS Instrument Approaches - General 5.38
Non - ILS Instrument Approaches 5.31
Non-ILS Approach Considerations 5.33
Non-ILS Instrument Approach Profile - One Engine Inoperative 5.56
Non-ILS Instrument Approach VNAV 1 ENG INOP FMA Progression 5.57

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Non-Normal Operations 5.52
Non-Normal Situation Guidelines 8.1
Nose Wheel/Rudder Pedal Steering 2.12

O

Obstruction Clearance 5.46
Optimum Altitude - Cruise 4.8
Other Modes of Descent 4.20
Overspeed 8.30
Overweight Landing 6.27

P

Partial or Gear Up Landing 8.27
Performance Considerations 10.9
Pitch and Roll Limit Conditions 6.11
Pitch Modes - Takeoff 3.19
Precision Approach Path Indicator (PAPI) 6.3
PRM Breakout Maneuver 5.26
Procedure Turn and Initial Approach - ILS 5.20
Procedure Turn 5.2
Push Back or Towing 2.1

Q

Quick Reference Landing Length 5.3

R

Radio Altimeter 5.2
Raw Data - (No Flight Director) - ILS 5.25
Recommended Technique for an In-Flight Engine Shutdown 8.11
Reduced and Derated Takeoff Thrust 3.7
Reduced Takeoff Thrust (ATM) 3.8
Reference Bugs 1.19
Rejected Landing 6.12
Rejected Takeoff Decision 3.11
Rejected Takeoff Maneuver 3.13
Reverse Thrust Operation - Landing Roll 6.22
RNAV Operations 1.23
Roll Modes - Takeoff 3.19

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Rotation and Liftoff - All Engines 3.4
Rotation and Liftoff - One Engine Inoperative 3.27
Rudder Trim Technique - Recommended 1.21
Runaway Stabilizer 8.22
Runway Markings (Typical) 6.5

S

Situations Beyond the Scope of Non-Normal Checklists 8.34
Speedbrakes 4.22
Stabilizer Trim Inoperative 8.21
Stall or Approach to Stall Recovery Maneuver 7.14
Stall or Approach to Stall 7.14
Steam Hydroplaning (Reverted Rubber) 10.19
Steep Turns 7.20
Stopping Dynamics 10.8
Structural Aspects of Maneuver 10.32

T

Tail Strike 3.16
Takeoff - Adverse Runway Conditions 3.9
Takeoff - Combination ATM and Fixed Derate 3.8
Takeoff - Crosswind 3.6
Takeoff - Engine Failure 3.27
Takeoff - Reduced and Derated Takeoff Thrust 3.7
Takeoff - Tail Clearance 3.4
Takeoff Crosswind Guidelines 3.6
Takeoff Profile - Normal - NADP 2 . . . . . 3.21
Takeoff Profile - Special - NADP 1 . . . . . 3.24
Takeoff Segments 10.2
Takeoff 3.1
Taxi - Adverse Weather 2.23
Taxi - Engine Out 2.10
Taxi - Minimum Radius 2.17
Taxi Speed and Braking 2.10
TEM - Error Management 9.11
TEM - Error 9.8

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Terrain Avoidance 7.22
Threshold Height 6.6
Thrust Use - Taxi 2.4
Thrust Vector Diagrams 2.6
Tire Failure during or after Takeoff 8.26
Traffic Alert and Collision Avoidance System 7.24
Trailing Edge Flap Asymmetry - Landing 8.18
Transition to Climb 4.3
Troubleshooting 8.2
Turbulence Avoidance 10.14
Turbulent Air Penetration 1.27
Turning Performance 10.12
Turning Radius Diagram 2.16

U

Upset Recovery 7.28

V

Vertical Guidance On a Visual Approach 5.50
Viscous Hydroplaning 10.19
Visual Aim Point 6.4
Visual Approach - Downwind and Base Leg 5.49
Visual Approach - Final Approach 5.50
Visual Approach - General 5.49
Visual Approach - Internal Visual Cues 5.49
Visual Approach Slope Indicator (VASI/T - VASI) 6.1
Visual Traffic Pattern Profile 5.51
Visual Traffic Pattern 5.49

W

Weather Radar 10.14
Window Damage 8.33
Window(s) Open 8.33
Windshear Avoidance 10.16
Windshear 7.34

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