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747-400 Flight Crew Training Manual Delta Air Lines, Inc.

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Preface

Model Identification

Chapter PT

Section 1

General

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

The table permits flight crew correlation of configuration differences by Registry Number in alpha/numeric order within an operator's fleet for aircraft covered in this manual. Configuration data reflects the aircraft as delivered configuration and is updated for service bulletin incorporations in conformance with the policy stated in the introduction section of this chapter.

Ship number is supplied by the operator. Registry number is supplied by the national regulatory agency. Serial and tabulation numbers are supplied by Boeing.

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 aircraft. 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	Registry Number	Serial Number	Tabulation Number
6301	N661US	23719	RT401
6302	N662US	23720	RT402
6303	N663US	23818	RT403
6304	N664US	23819	RT404
6305	N665US	23820	RT405
6306	N666US	23821	RT406
6307	N667US	24222	RT407
6308	N668US	24223	RT408
6309	N669US	24224	RT409
6310	N670US	24225	RT410
6311	N671US	26477	RM241
6312	N672US	30267	RM242
6313	N673US	30268	RM243
6314	N674US	30269	RM244
6315	N675NW	33001	RM245
6316	N676NW	33002	RM246

Preface

Introduction

Chapter PT

Section 2

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, i.e., stall recovery and emergency descent. The Non-Normal Procedures 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 do 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 calls.

Note: In the event of a conflict, the procedures and restrictions published in the Vol. 1, Vol. 2, QRH, MEL, Flight Crew 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.

Any questions about the content or use of this manual can be directed to:

Fleet Page on DeltaNet
Flight Operations Manuals
Pilot Manual & Revision Order Forms
FCTM, FOM, Vol. 1, Vol. 2, & QRH Subscriptions
Publications Change Request

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.

Aircraft Configuration

The Flight Crew Training Manual (FCTM) is intended to provide information in support of procedures listed in the Vol. 1 and QRH 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 Vol. 1 and QRH. The FCTM does not account for aircraft 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 maneuver 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 Vol. 1 is required for information on how to set climb thrust.

In cases where a procedure or technique is applicable only to an aircraft with a specific configuration, the annotation “as installed” is used. Aircraft configuration differences are found in the Vol. 1.

Manual Rights

The 747-400 Operations Manual has been prepared for the exclusive use of Delta Air Lines, Inc., Flight Operations personnel under the direction and authority of Delta and shall, at all times, remain the property of Delta. The holder hereof acknowledges and agrees that this manual contains or may contain trade secrets, copyrighted material and commercial and proprietary information, privileged and confidential, to the interest of Delta, and the holder hereof further agrees that this manual may not be reproduced, distributed or copied, in whole or in part, without the express prior written consent of Delta.

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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 Pilot Bulletin (APB).

There is a link to the PCR form at Deltanet > My Division > Pilot Support > 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.

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.

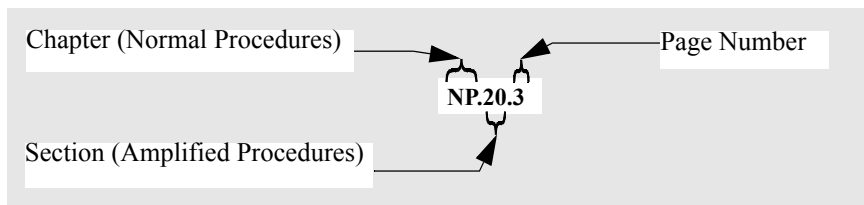
FCTM

- 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, techniques, and human factors.

Page Numbering

This manual uses a decimal page numbering system. The page number is divided into three fields; chapter, section, and page. An example of a page number for the Normal Procedures chapter follows:

Example Page Number



Warnings, Cautions, and Notes

The following levels of written advisories are used throughout the manual and are not to be confused with EICAS messages, which are identified in separate text.

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.

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.

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Abbreviations

Chapter PT

Section 3

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
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
ALFA	Safe Stall Margin Speed
ALT	Altitude
ALT ACQ	Altitude Acquire
ALT HOLD	Altitude Hold
ALTN	Alternate
AM	Amplitude Modulation

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AIMS	Airplane Information Management System
AMI	Airline Modifiable Information
ANP	Actual Navigational Performance
ANT	Antenna
ANU	Aircraft Nose Up
AOA	Angle of Attack
AOC	Airline Operational Communication Data Link
A/P	Autopilot
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
BTL DISCH	Bottle Discharge (fire extinguisher)
BTMS	Brake Temperature Monitoring System

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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
CANPA	Constant Angle Non-Precision Approach
CAP	Capture
CAPT	Captain
CAWS	Central Aural Warning System
CB	Circuit Breaker
CCD	Cursor Control Device
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
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
EQPT or EQUIP	Equipment
ETOPS	Extended Range Operation with Twin Engine Airplanes
ETP	Equal Time Point
EVAC	Evacuation
EXEC	Execute

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EXT	Extend or External
F	
F	Fahrenheit or First Officer
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
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
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

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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	Locator Outer Marker
LON	Longitude
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-purpose Control and Display Unit
MCO	Maintenance Carry Over
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

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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
MUH	Minimum Use Height
MVA	Minimum Vectoring Altitude
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)
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

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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
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
PNF	Pilot Not Flying
PNL	Panel
POS	Position
POS INIT	Position Initialization
POS REF	Position Reference
PPI	Planned Position Indicator
PPOS	Present Position
PRES or PRESS	Pressure
PREV	Previous
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
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
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

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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
TERPS	Terminal Instrument Procedures
TERR	Terrain
TFC	Traffic
TFR	Transfer
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 Air Speed or 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
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

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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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Preface

Revision Record

Chapter PT

Section 4

Revision Transmittal Letter

To: All holders of the Delta Air Lines, Inc. Flight Crew Training Manual.

Subject: Flight Crew Training 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	No.	Revision Date	Date Filed
0	June 5, 2014		1	December 2, 2014	
2	March 25, 2016		3	September 23, 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 web address for Deltanet.

PT.2.3 - Updated Deltanet path to the PCR submission form.

Section 3 - Abbreviations

PT.3.5 - Added First Officer as a definition for abbreviation F.

Section 4 - Revision Record

PT.4.1 - Removed extraneous sentence.

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

PT.4.1 - Removed Filing Instructions section.

PT.4.2 - Revised to match the electronic-only method.

Chapter 1 - General Information

Descent

1.11 - Added Descent Flow.

Chapter 2 - Ground Operations

Delta De/Anti-icing Program

2.26,28 - Changed Delta Special Pages to Company Pages.

Engine Running De/Anti-Icing

2.31 - Changed Delta Special Pages to Company Pages.

Communication Procedures

2.35 - Changed Delta Special Pages to Company Pages.

Chapter 3 - Takeoff and Initial Climb

Takeoff

3.1 - Changed Delta Special Pages to Company Pages.

Gusty Wind and Strong Crosswind Conditions

3.8 - Changed sentence to: Consider the use of a higher thrust setting than the minimum required.

Assumed Temperature Method (ATM)

3.9 - Changed Delta Special Pages to Company Pages.

Adverse Runway Conditions

3.11-12 - Updated SP.16 reference.

RNAV Departures

3.34-39 - Added new section.

Takeoff Profile - Engine Failure

3.46 - Modified the language in the Note.

Chapter 4 - Climb, Cruise, Descent and Holding

Descent Planning

4.19 - Modified language.

STAR and RNAV STAR Descents

4.19-23 - Added new section for STAR and RNAV STAR Descents.

4.23 - Relocated and updated Calculation of 3:1 Descent Ratio.

Descent Speed Determination

4.24 - Modified language.

Descent Path

4.24 - Modified language.

Descent Constraints

4.25 - Under Descent Constraints, moved information regarding VNAV PTH pitch mode requiring use of speedbrakes or thrust to maintain airspeed.

4.25 - Under Descent Constraints, in Note, clarified description of DRAG REQUIRED message.

4.25 - Under Descent Constraints, revised Note for clarity.

Speed Intervention

4.25 - Under Speed Intervention, moved information regarding VNAV PTH pitch mode requiring use of speedbrakes or thrust to maintain airspeed.

4.25 - Under Speed Intervention, deleted Notes; redundant.

4.25 - Under Speed Intervention, added information for ATC speed reduction.

4.26 - Under Speed Intervention, revised information for FMS approach mode.

Early Descent from Cruise

4.26 - Revised Early Descent from Cruise to match current practice.

Chapter 5 - Approach and Missed Approach

STAR/RNAV STAR Common Runway Transition Approach Clearance

5.3 - Added new section.

RNAV Visual Common Runway Transition Approach Clearance

5.4-5 - Added new section.

Approach

5.14 - Revised language to increase awareness of potential premature G/S capture and the technique to avoid this issue.

5.19 - Updated SP.16 reference.

GPS, RNAV (GPS), or RNAV (GNSS) Approach Considerations Expanded Approach Guide LNAV & VNAV Modes

5.27 - Revised language in the RNAV briefing for cross-fleet standardization.

Go-Around and Missed Approach - All Engines Operating

5.83 - Changed Delta Special Page to Company Pages.

5.84 - Changed Delta Special Pages to Company Pages.

Chapter 6 - Landing

Visual Approach Slope Indicator (VASI / T-VASI)

6.1 - Grammar correction.

Three Bar VASI / T-VASI

6.2 - Grammar correction.

Crosswind Landings

6.30 - Updated SP.16 reference.

Chapter 7 - Maneuvers

Traffic Alert and Collision Avoidance System

7.19-22 - Revised the language in the TCAS section, incorporating FB 16-06 TCAS Resolution Advisory (RA) Policy Update.

Chapter 9 - Human Factors

CRM Skills

9.8 - Changed Special Pages to Company Pages.

The Highest Threat

9.13 - Changed Delta Special Pages to Company Pages.

Chapter 10 - Selected References

Departure Procedures (DPs)

10.8 - Changed 10-7 Delta Special Pages to Company Pages.

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Preface

Chapter PT

List of Effective Pages - FAA Approved

Section 5

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* PT.2.1-6	September 23, 2016
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Revision Record	
* PT.4.1-6	September 23, 2016
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* = Revised, Added, or Deleted

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General Information

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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, and
- mitigate the consequences of an error after detection.

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

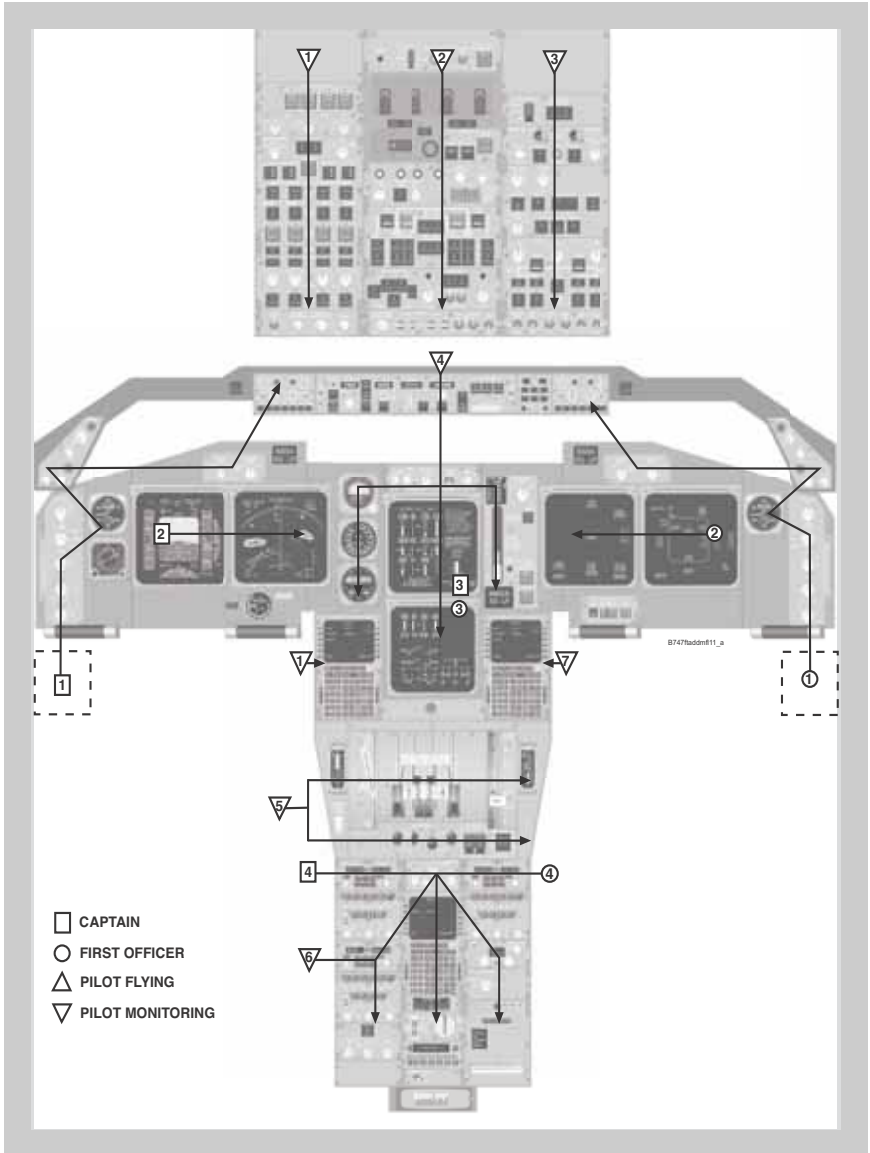
- situational awareness,
- decision making,
- planning,
- communication,
- workload management, and
- professional management.



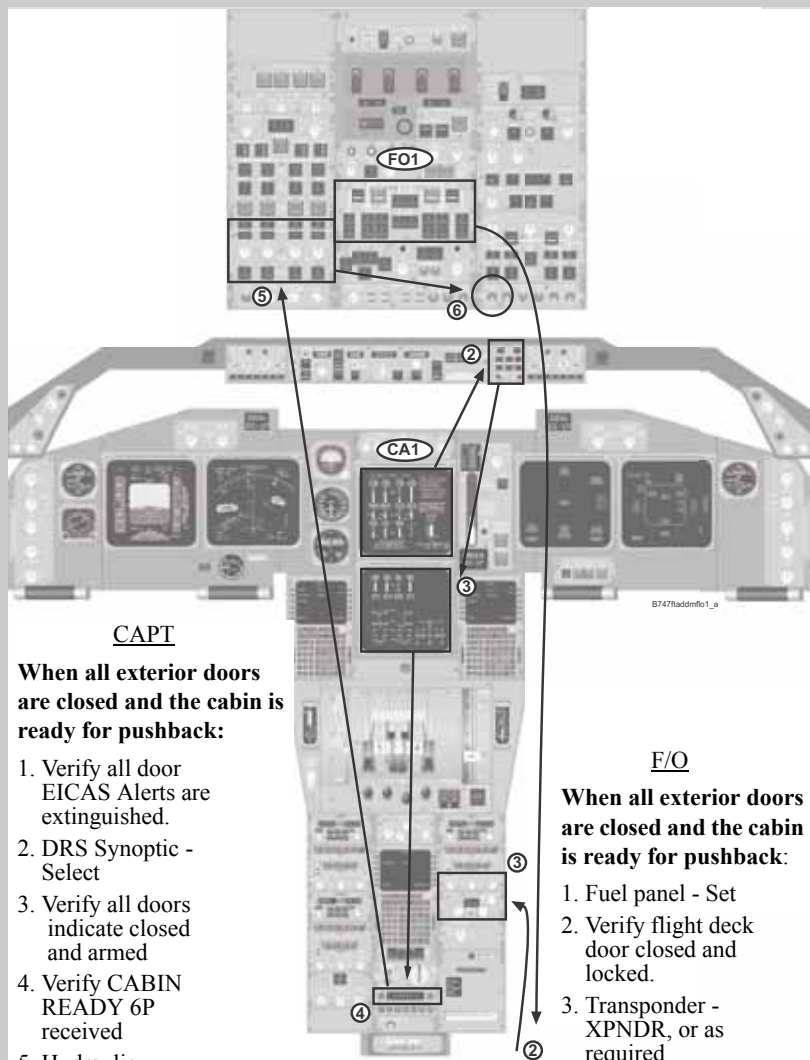
Flow Pattern Diagrams

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.

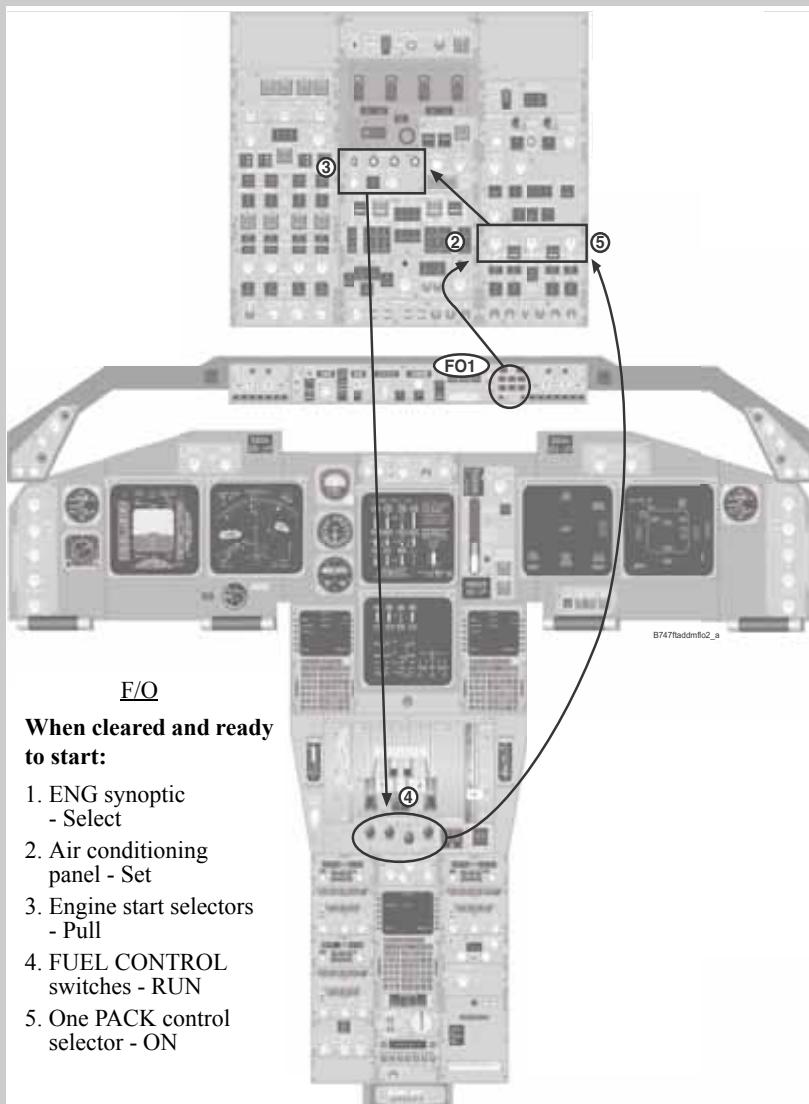
Preflight Flow



Pushback



Engine Start

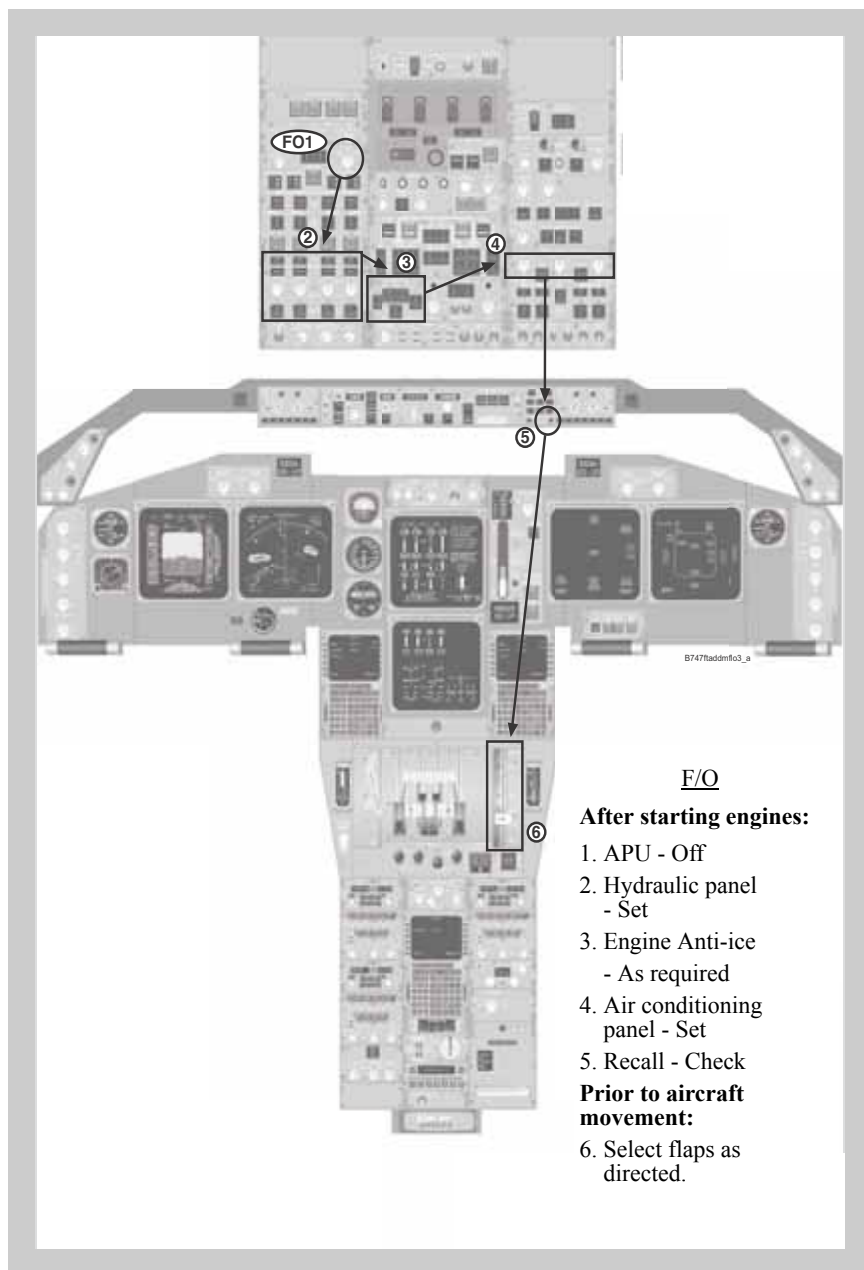


E/Q

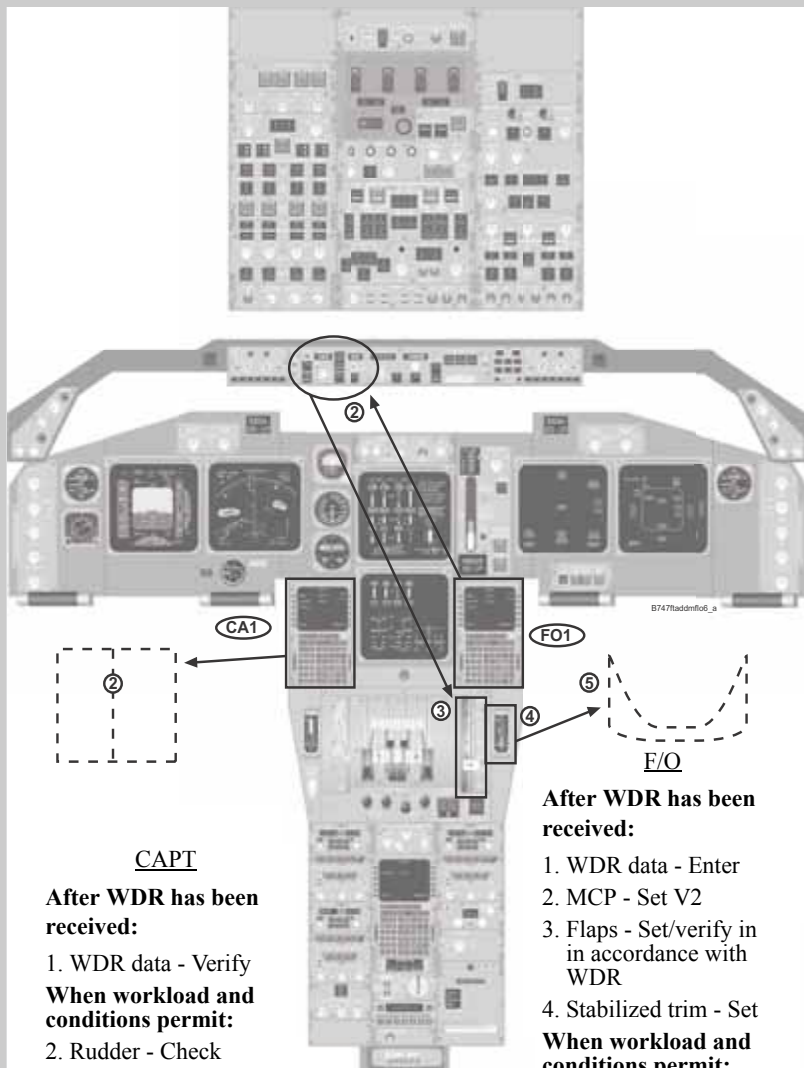
When cleared and ready to start:

1. ENG synoptic
- Select
2. Air conditioning
panel - Set
3. Engine start selectors
- Pull
4. FUEL CONTROL
switches - RUN
5. One PACK control
selector - ON

After Start



Taxi



CAPT

After WDR has been received:

1. WDR data - Verify
- When workload and conditions permit:**
2. Rudder - Check

After WDR has been received:

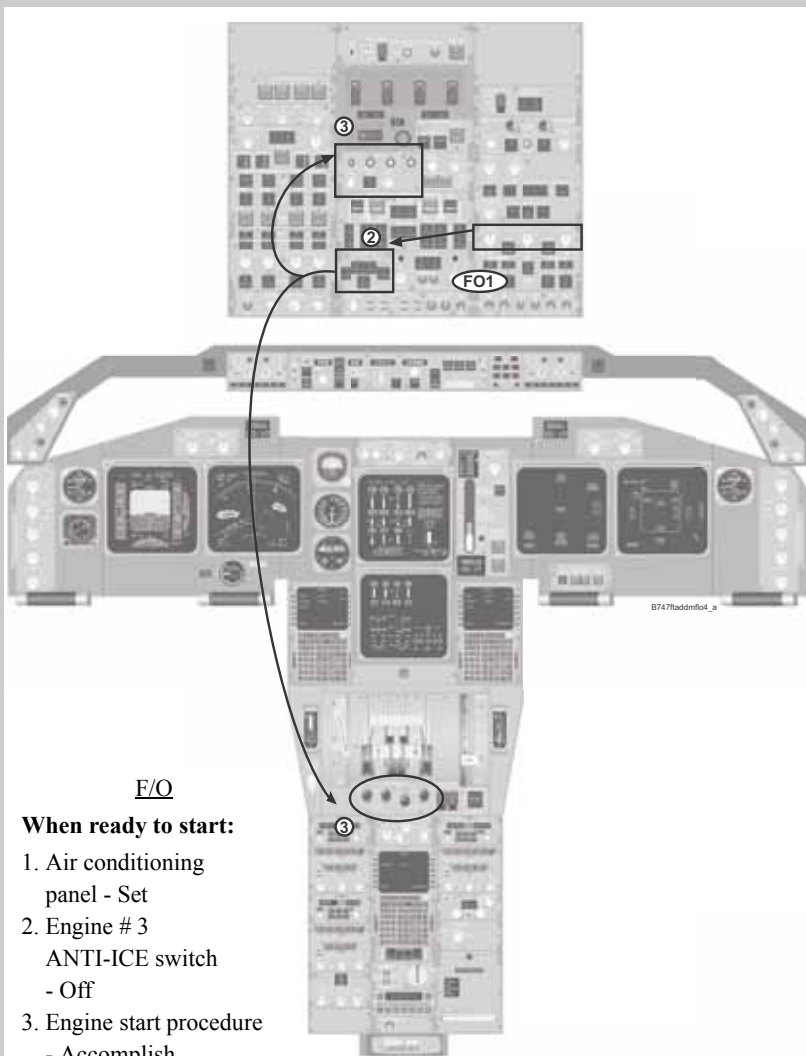
1. WDR data - Enter
2. MCP - Set V2
3. Flaps - Set/verify in accordance with WDR

When workload and conditions permit:

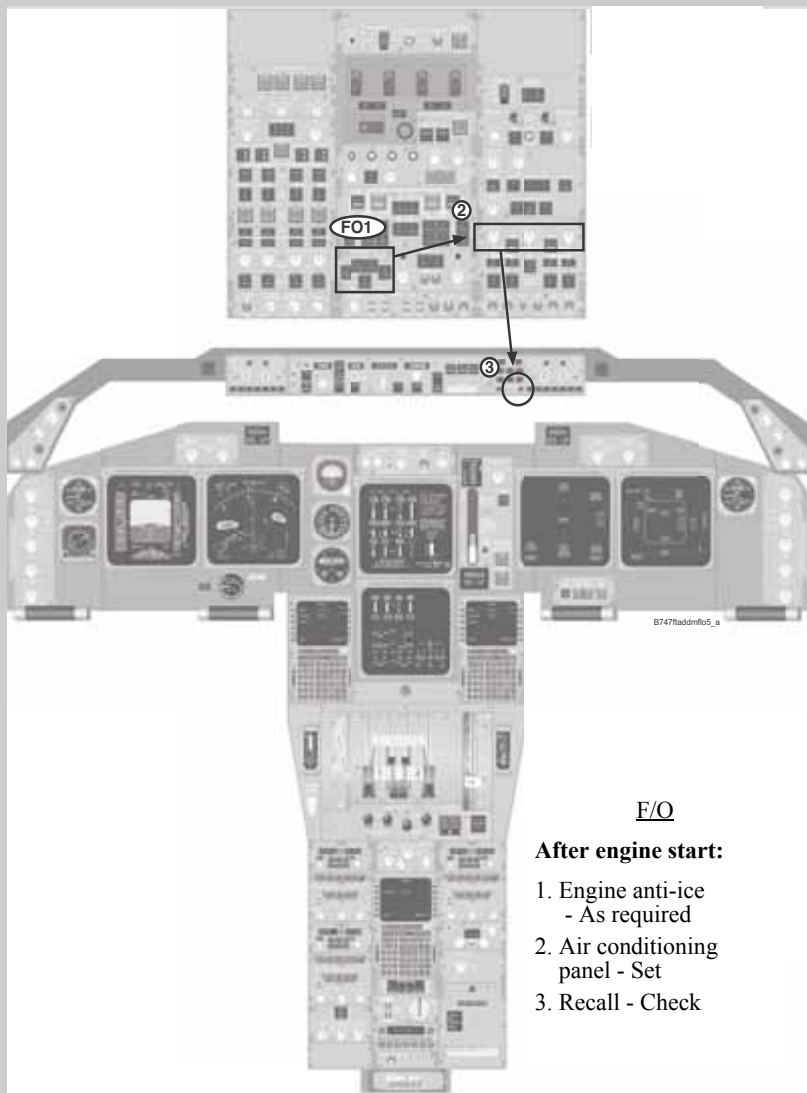
4. Stabilized trim - Set
- When workload and conditions permit:**
5. Aileron and elevator - Check

Note: The WDR data may be loaded at any point after receipt of the WDR.

Delayed Start



Delayed After Start

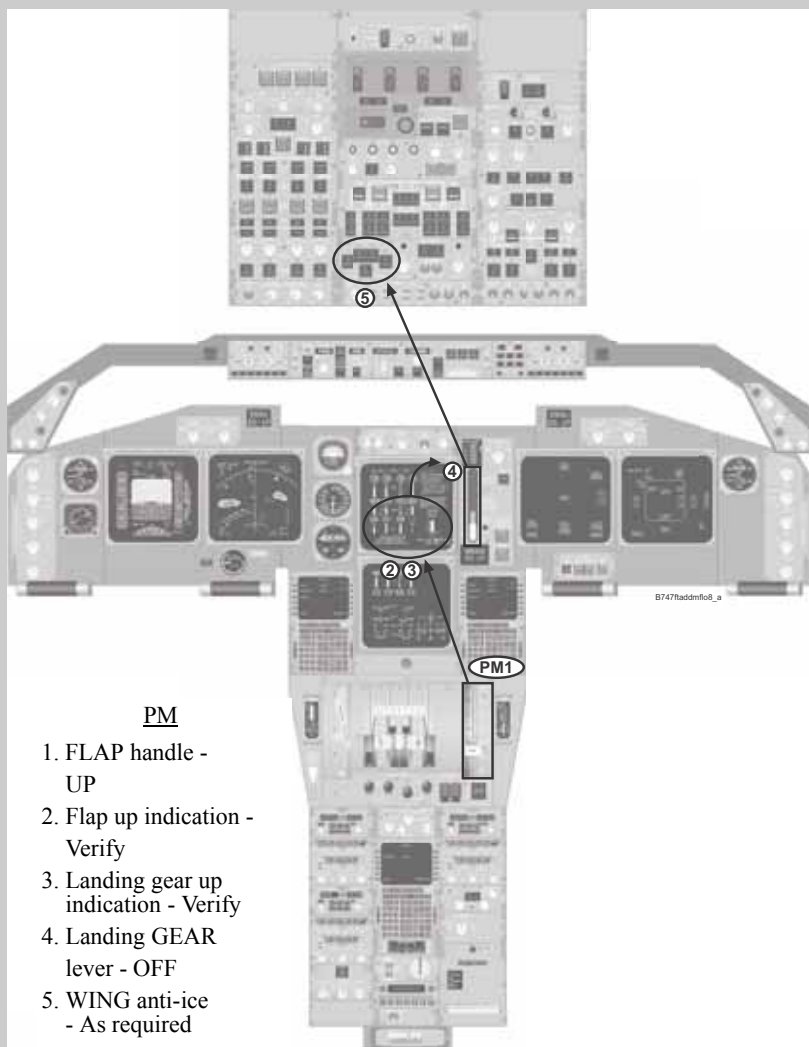


F/O

After engine start:

1. Engine anti-ice
- As required
2. Air conditioning
panel - Set
3. Recall - Check

After Takeoff



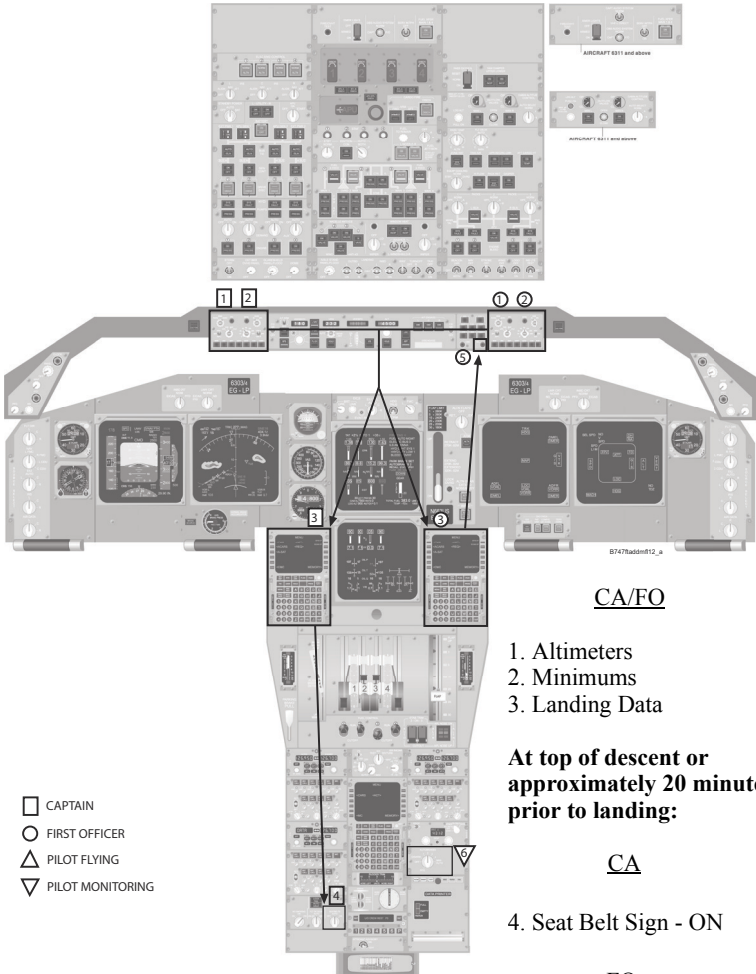
PM

1. FLAP handle - UP
2. Flap up indication - Verify
3. Landing gear up indication - Verify
4. Landing GEAR lever - OFF
5. WING anti-ice - As required



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Descent

CA/FO

1. Altimeters
2. Minimums
3. Landing Data

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

CA

4. Seat Belt Sign - ON

FO

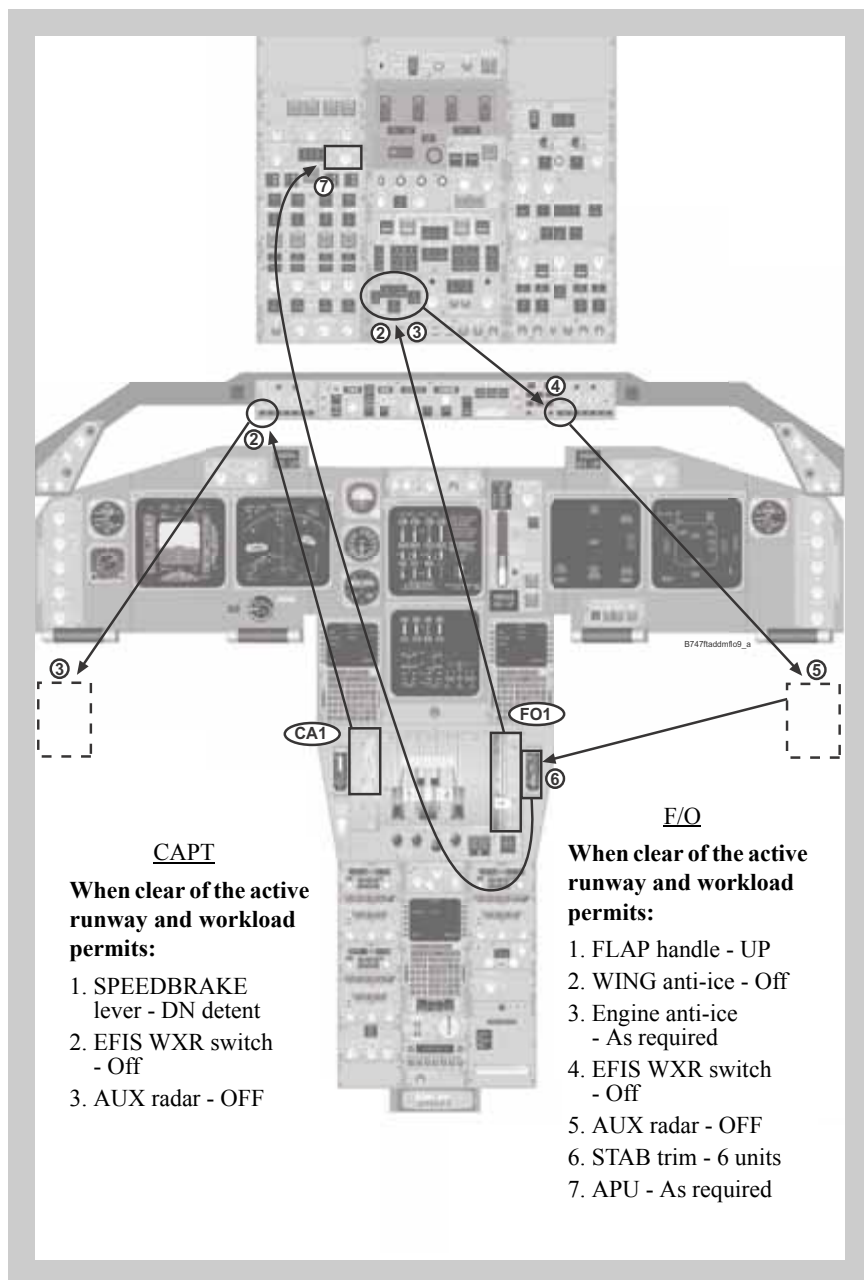
5. Recall - Check

PM

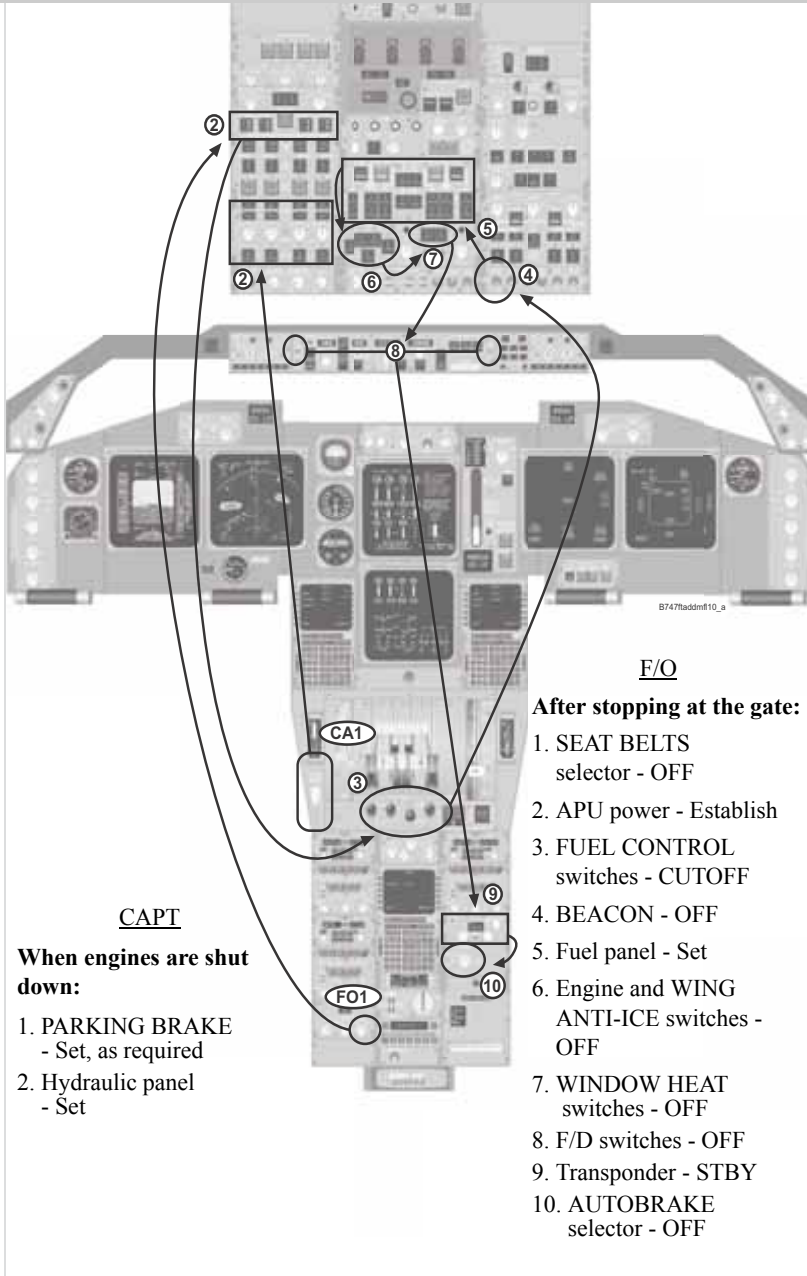
6. Autobrakes - as reqd

- ☐ CAPTAIN
☐ FIRST OFFICER
 PILOT FLYING
 PILOT MONITORING

After Landing



Shutdown



Synoptic Display

Synoptic displays are provided as a means of assisting the flight crew in rapidly understanding the status of the aircraft systems. However, crews should not rely solely on the displays for determining aircraft status. The flight crew is encouraged to select a display any time they feel it is the most efficient way to get desired information. Synoptic displays should only be used as necessary to get the desired information and then turned off. The clarity and simplicity of displayed information enables the flight crew to obtain necessary information from a brief scan.

Note: Reference to synoptic displays or maintenance information is not a requirement during the accomplishment of crew procedures.

If the flight crew elects to use synoptic displays in conjunction with accomplishment of procedures, they must ensure no distraction from the intended task results. This is particularly true when accomplishing non-normal procedures. Under certain conditions, system faults can result in missing synoptic information. Therefore, decisions regarding non-normal situations should be based on EICAS messages and other flight deck effects and indications. In every case where a non-normal procedure results in a need for memory items, the memory items should be completed before selecting a synoptic display. Accomplishment of necessary procedures should take priority over use of synoptic displays.

Maneuver Speeds and Margins

This section explains the difference between flap maneuver speeds and minimum maneuver speeds. It also describes maneuver margin or bank capability to stick shaker as a function of airspeed during both a flap extension and flap retraction scenario.

Flap Maneuver Speeds

The following tables contain flap maneuver speeds for various flap settings. The flap maneuver speed is the recommended operating speed during takeoff or landing operations. These speeds guarantee full maneuver capability or at least 40° of bank (25° of bank and 15° overshoot) to stick shaker within a few thousand feet of the airport altitude. While the flaps may be extended up to 20,000 feet, less maneuver margin to stick shaker exists for a fixed speed as altitude increases.

Note: The flap maneuvering speeds should not be confused with the minimum maneuver speed which is displayed as the top of the lower amber band on the airspeed display.

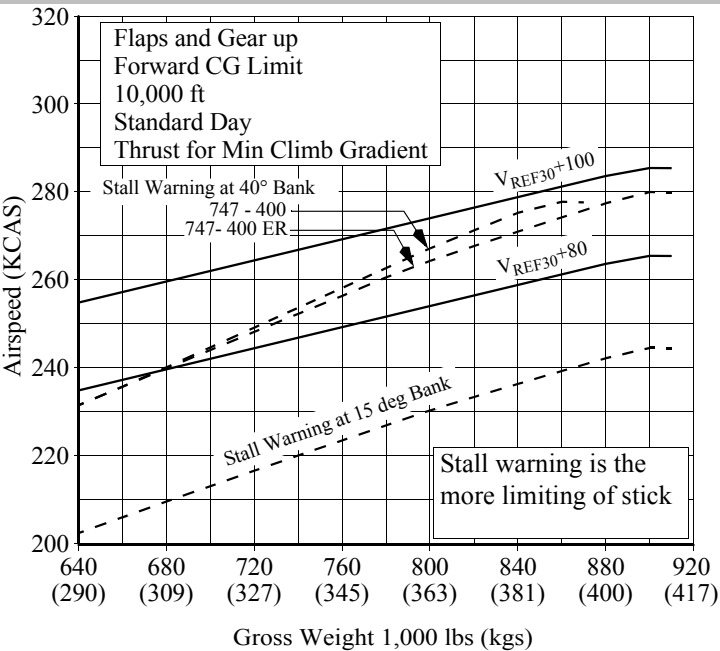
Flap Position	All Weights
Flaps UP	VREF 30 + 80*
Flaps 1	VREF 30 + 60
Flaps 5	VREF 30 + 40
Flaps 10	VREF 30 + 20
Flaps 20	VREF 30 + 10
Flaps 25	VREF 25
Flaps 30	VREF 30
* Above 680,000 lbs (309,000 kgs) full maneuvering capability is not obtained until reaching VREF 30 + 100 knots.	

Flaps Up Maneuvering

The following figure illustrates full maneuver capability for at least 40° of bank (25° bank + 15° overshoot) in the clean configuration. Full maneuvering capability is not available at flaps up speed (VREF 30 + 80) at gross weights greater than 680,000 lbs (309,000 Kgs). At high gross weights, limit bank angle to 15° until 20 knots above the flaps up speed (PFD command speed “UP” symbol + 20 knots).



Flaps Up Maneuvering Capability



Minimum Maneuver Speed

The top of the lower amber band on the airspeed display indicates the minimum maneuver speed. The functionality of the lower amber band is slightly different for flaps-down versus flaps-up operation, however, in both cases it alerts the crew that when operating at an airspeed within the amber band less than full maneuver capability exists.

Note: During normal conditions, the target speed is always equal to or faster than the minimum maneuver speed (top of the amber band). During non-normal conditions, the target speed may be below the minimum maneuver speed.

Flaps Down Amber Band

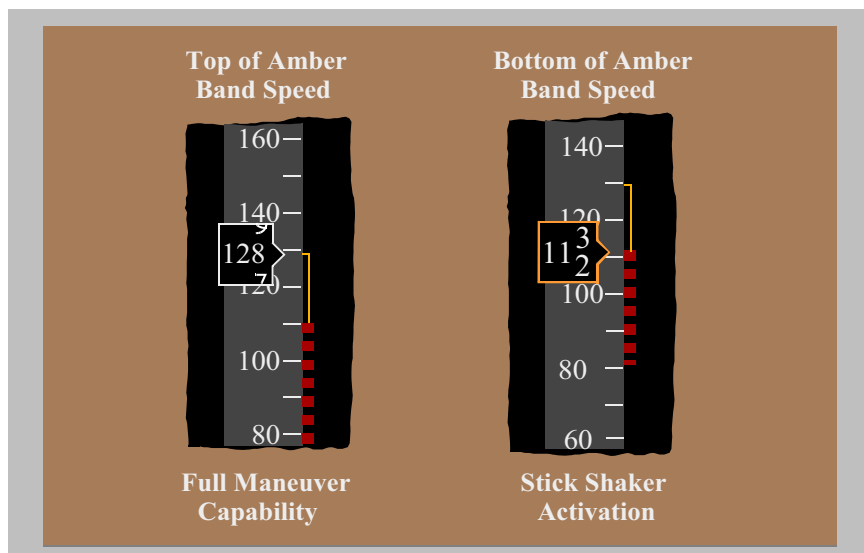
For all flaps-down operations (any time the flaps are not full-up) the minimum maneuver speed is the slowest speed that provides full maneuver capability, 1.3 g's or 40° of bank (25° angle of bank and 15° overshoot) to stick shaker. The top of the amber band does not vary with g load.

As airspeed is decreased below the top of the amber band, maneuver capability decreases. In 1g flight, the speed in the middle of the amber band provides adequate maneuver capability or 30° of bank (15° angle of bank and 15° overshoot). The speed at the bottom of the amber band (top of the red and black tape) corresponds to stick shaker onset for the current g load. If the g load is increased during maneuvering, the stick shaker onset speed increases also.

Airspeed Location in Amber Band	Maneuver Capability	Bank Angle	Overshoot	Bank Capability to Stick Shaker
Top	Full	25°	15°	40°
Middle	Adequate	15°	15°	30°
Bottom	Stick shaker activation.			

Note: Stick shaker is set to activate before the actual stall. There is sufficient margin to recover from stick shaker without stalling.

The following diagram shows airspeed location relative to the amber band.



Minimum maneuver speeds (displayed as the top of the lower amber band) should not be confused with flap maneuver speeds. Flap maneuver speeds are based on aircraft weight, while the minimum maneuver speed is calculated using aircraft angle of attack and current airspeed. These speeds provide independent means to ensure that the current airspeed provides at least full maneuver capability for terminal-area maneuvering.

Note: During normal conditions, the flap maneuver speed for the current flap detent should always be equal to or faster than the minimum maneuver speed. During some non-normal conditions, the flap maneuver speed for the current flap position may be less than the minimum maneuver speed.

Flaps Up Amber Band

Below approximately 20,000 feet, the flaps-up amber band will not exceed the UP speed bug at $V_{REF} 30 + 80$. As discussed in the section titled Flaps Up Maneuvering, this speed does not provide full maneuver capability for weights above 680,000 lbs. For lighter weights at altitudes up to approximately 10,000 feet, the flaps-up amber band functions just like the flaps-down amber band described above, with the top of the amber band representing full maneuver capability. Due to increasing Mach effects between 10,000 and 20,000 feet, the maneuver capability at the top of the amber band speed decreases as altitude increases. Above approximately 20,000 feet, the top of the amber band shows the speed that provides 1.3g maneuver capability to low speed buffet (or an alternative approved maneuver capability as preset by maintenance).

Maneuver Margins

The following figures are representative illustrations of aircraft maneuver margin or bank capability to stick shaker as a function of airspeed. This includes both a flap extension and flap retraction scenario.

When reviewing the maneuver margin illustrations, note that:

- 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°.
- The illustrated maneuver margin assumes a constant speed, level flight condition.
- Stick shaker activates prior to actual stall speed.
- Flap retraction or extension speed is that speed where the flaps are moved to the next flap position in accordance with the flap retraction or extension schedule.
- 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. In level flight they provide a relatively constant pitch attitude and require little change in thrust at different flap settings.
- The bold line designates flap configuration changes at the scheduled flap retraction or extension speeds.
- The black dots on the bold lines indicate:
 - maneuver speed for the existing flap setting and
 - flap retraction or extension speed for the next flap setting.

The distance between the bold line representing the flap extension or retraction schedule and a given bank angle represents the maneuver margin to stick shaker at the given bank angle for level constant speed flight. Where the flap extension or retraction schedule extends below a depicted bank angle, stick shaker activation can be expected prior to reaching that bank angle.

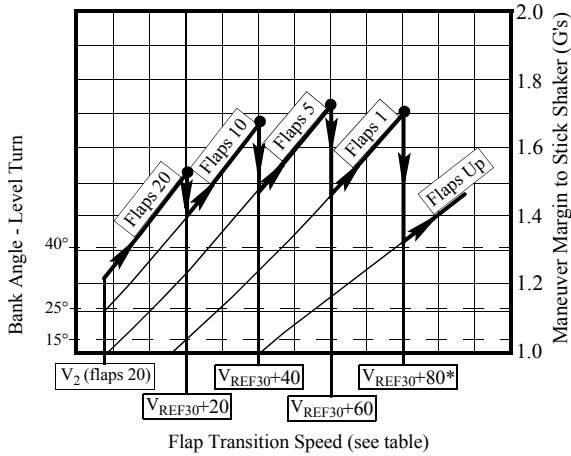
Conditions Affecting Maneuver Margins to Stick Shaker

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 V_{REF}) 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.
- Landing gear: A small decrease in maneuver margin may occur when the landing gear is extended. This loss is equivalent to 2 knots of airspeed or less.
- Speedbrakes: generally maneuver margin decreases when speedbrakes are extended.
- Engine failure during flap retraction: a small decrease in maneuver margin occurs due to the reduced lift experienced with the loss of thrust. The loss is equivalent to 4 knots of airspeed or less.
- Anti-ice: The use of nacelle or wing anti-ice has no effect on maneuver margin.

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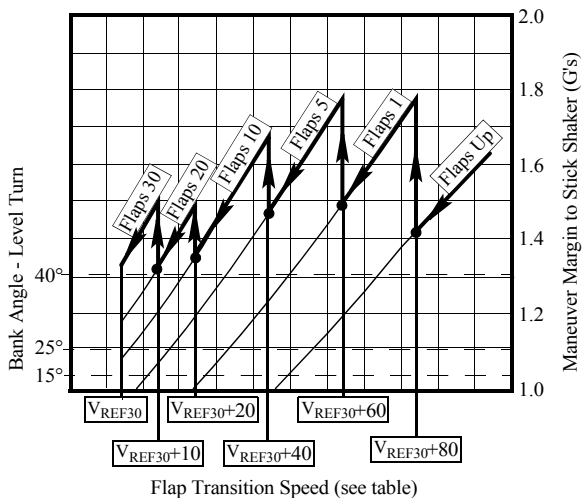
Maneuver Margins to Stick Shaker - Flap Retraction



Takeoff Flaps	At "Display"	Flap Transition Speed	Select Flaps
20	"10"	Vref 30 + 20	10
	"5"	Vref 30 + 40	5
	"1"	Vref 30 + 60	1
	"UP"	Vref 30 + 80*	UP
10	"5"	Vref 30 + 40	5
	"1"	Vref 30 + 60	1
	"UP"	Vref 30 + 80*	UP
*Above 680,000 lbs (309,000 kgs), limit bank angle to 15° with flaps up until reaching UP + 20 knots.			



Maneuver Margins to Stick Shaker - Flap Extension



Current Flap Position	At Speedtape "Display"	Flap Transition Speed	Select Flaps	Command Speed for Selected Flaps
UP	"UP"	VREF 30 + 80*	1	"1"
1	"1"	VREF 30 + 60	5	"5"
5	"5"	VREF 30 + 40	10	"10"
10	"10"	VREF 30 + 20	20	"20"
20	"20"	VREF 30 + 10	25 or 30	VREF + 5 knots or VREF + wind additive
*Above 680,000 lbs, use UP + 20. VREF 30 + 100.				

Command Speed

Command speed may be set by the pilot through the MCP or FMS and is displayed as command speed on the airspeed display.

Takeoff

Command speed remains set at V₂ until changed by the pilot for acceleration or until Vertical Navigation (VNAV), Flight Level Change (FLCH), or altitude hold is engaged. When using FLCH or when altitude hold engages, increase command speed to the desired speed to initiate acceleration for flap retraction.

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 an appropriate buffer from V_{mo}/M_{mo} and flap placard speeds.

Approach

Command speed is set to the maneuver speed for the selected flap position manually using the MCP.

Landing

When using the autothrottle to touchdown, 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.

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. 1/2 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 approach 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

Occasionally, a non-normal checklist instructs the flight crew to use a VREF speed that also includes a speed additive such as VREF 25 + 15. When VREF has been adjusted by a NNC, this becomes the VREF used for landing. This VREF does not include wind additives. For example, if a non-normal checklist specifies “Use flaps 25 and VREF 25 + 15 for landing,” the flight crew would select flaps 25 as the landing flaps and look up the VREF 25 speed in the FMS or ODM and add 15 knots to that speed.

When using the autothrottle, position command speed to VREF + 5 knots. Sufficient wind and gust protection is available with the autothrottle connected that no further wind additives are needed.

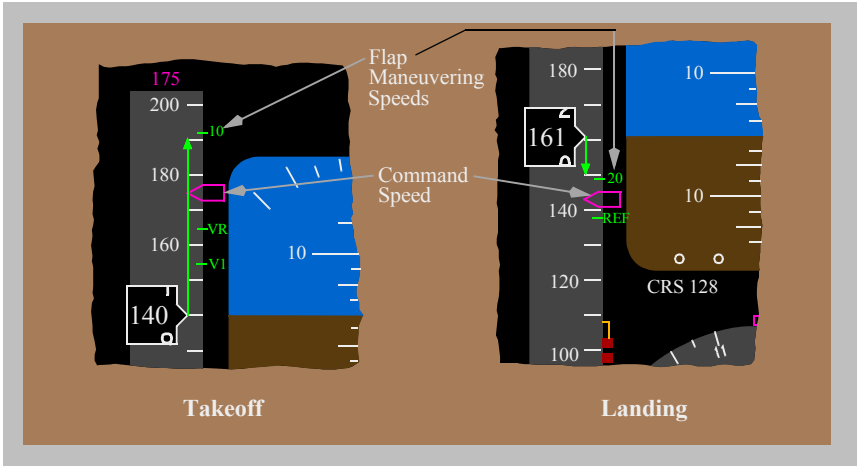
If the autothrottle is disconnected, or is planned to be disconnected prior to landing, appropriate wind additives must be added to the VREF to arrive at command speed, the speed used to fly the approach. For example, if the checklist states “use VREF 30 + 20 knots”, command speed should be positioned to VREF (VREF 30 + 20) plus wind additive (5 knots minimum, 20 knots maximum).

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Reference Speeds

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

Reference Speed Setting



Takeoff

After zero fuel weight, V1, VR, and V2 are entered into the FMS, airspeed bugs are automatically displayed at V1, VR, V2, and the minimum flap retraction speed for the next flap position. Command speed is set at V2 using the MCP. V2 is the minimum takeoff safety speed and provides at least 30° bank capability (15° + 15° overshoot) for all takeoff flaps.

Approach - Landing

VREF is displayed upon entry of landing flaps/speed in the FMS. The maneuver speed for the current flap position and the next flap position are automatically displayed on the airspeed display.

Thrust Management

Setting Thrust

The term “set thrust” or “verify that thrust is set” is used in various places in the FCTM and the Vol. 1. The proper thrust setting is determined by the N1 or EPR indication. However, when setting or verifying the proper thrust is set, the flight crew's attention should not be focused on setting the exact indication at the expense of crosschecking that other engine indications are consistent with the N1 or EPR indication and maintaining situational awareness.

Maximum Thrust

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

- for aircraft with engine EECs operating in the normal mode, by advancing the thrust levers full forward,
- for aircraft with engine EECs operating in the alternate mode, by advancing the thrust levers to the full rated takeoff or go-around limit only. Advancing the thrust levers to the full forward stop should only be considered if terrain contact is imminent.

Note: This definition of maximum thrust applies to all situations except when a fixed derate takeoff is accomplished. The fixed derate is considered a limitation for takeoff. Refer to chapter 3, Reduced Thrust Takeoff for further explanation of thrust limitations during a fixed derate takeoff.

Flight Path Vector

The Flight Path Vector (FPV) displays Flight Path Angle (FPA) relative to the horizon line and drift angle relative to the center of the pitch scale on the attitude display. This indication uses inertial and barometric altitude inputs. The vertical flight path angle displayed by the FPV should be considered unreliable with unreliable primary altitude displays. The FPV can be used by the pilot in several ways:

- as a reference for establishing and maintaining level flight when the F/D is not in use or not available. When maneuvering the aircraft, adjust pitch to place the FPV on the horizon. This results in zero vertical velocity;
- as a crosscheck of the vertical flight path angle when established in a climb, descent, or on a visual final approach segment;

Note: When on final approach, the FPV does not indicate aircraft glide path relative to the runway. ILS glide slope, VASI/PAPI, or other means must be used for a proper glide path indication.

- in climbs or descents, radar tilt can be adjusted to an appropriate elevation based on the displayed FPA. Radar tilt, like the FPV, is referenced to the horizon. Example: Adjusting the radar tilt to the same angle relative to the horizon as the FPV during climb results in the radar beam centered on the existing flight path;
- as a qualitative indication of aircraft lateral drift direction if the map is not available. The FPV moves left or right of the pitch scale to indicate the relative position of the ground track to the present heading. The amount of drift cannot be determined from this display. Example: FPV displaced to the left indicates wind component from the right and corresponding drift to the left;
- as a cross-reference, when flying visual traffic patterns. On the downwind leg, the flight crew should position the FPV on the horizon line, in order to maintain level flight;
- on final approach it provides a trajectory that quickly indicates a downburst. In addition, the position of the FPV in relation to the aircraft symbol provides an indication of the wind direction; and
- as a reference by the pilot in maintaining proper flight path control with unreliable airspeed indications. Adjust pitch to establish desired flight path by placing the FPV just above, below or on the horizon line.

Note: The FPV should not be used in reference to the PLI, which is a pitch attitude referenced display.

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.

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 SEL or HDG HOLD and stabilized for at least 30 seconds, and
- 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 top 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 SEL or HDG HOLD and stabilized for at least 30 seconds, and
- 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 switches. 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.

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RNAV Operations

Delta Air Lines' 747-400 aircraft are not currently approved for RNAV (RNP) approaches.

This section provides definitions of terms associated with RNAV and describes basic concepts to include phase of flight navigation for radius-to-fix (RF) legs, 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.

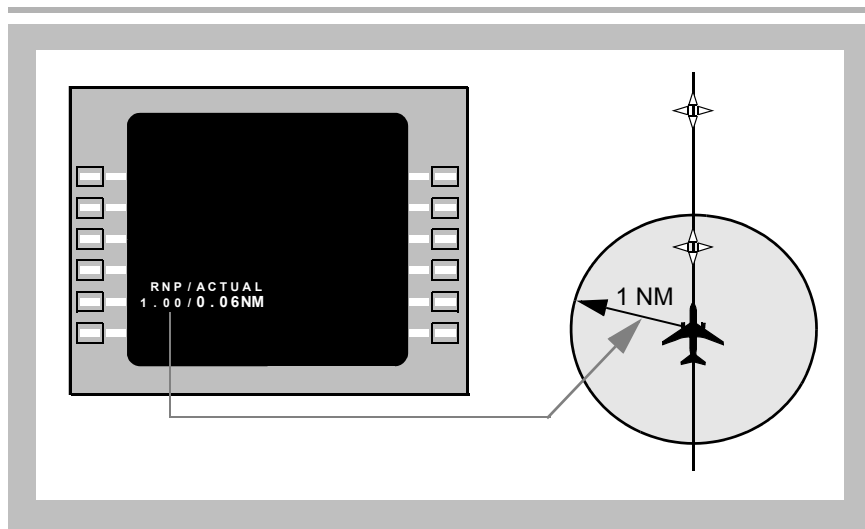
All FMSs are capable of performing RNAV operations. Regarding navigation accuracy, these FMSs differ only by demonstrated RNP capabilities and the ability to use GPS updating.

En-route operations can be defined as oceanic and domestic. Oceanic RNAV requirements are described in detail in the applicable MNPS guidance material such as the Pacific or North Atlantic manuals. Specific routes or areas of operation are given RNP based on route separation requirements. RNP 10 routes are suitable for all FMSs that are capable of GPS updating and those FMSs that cannot update from GPS but have received the last radio update within the previous six hours.

In general, oceanic operations require dual navigation systems (dual FMS or single FMS in combination with alternate navigation capability).

RNP and ANP Definitions

RNP (Required Navigation Performance) is a specified navigation performance for route, terminal, or approach procedures. It is a measure of the navigation performance accuracy necessary for operations within a defined airspace where the aircraft must be at least 95% of the time. It is shown in nautical miles. All RNP based procedures have an associated RNP level that is published on the procedure chart.



Oceanic RNP operations are generally 4.0 or higher. Domestic en-route RNAV operations depend on the availability of radio updating (DME-DME) sources to support domestic RNP operations. The following domestic RNP operations are fully supported by any Boeing FMS with DME-DME or GPS updating active:

- USA and Canada - RNP 2.0 or higher, RNAV-1, and RNAV-2;
- Europe - B-RNAV (RNP 5.0);
- Asia - As specified for the route or area (e.g. RNP 4 or RNP 10 routes); and
- Africa - As specified for the route or area.

Terminal RNAV operations (SIDs, STARs, and Transitions) are fully compatible with all FMSs with DME-DME or GPS updating active and are defined as:

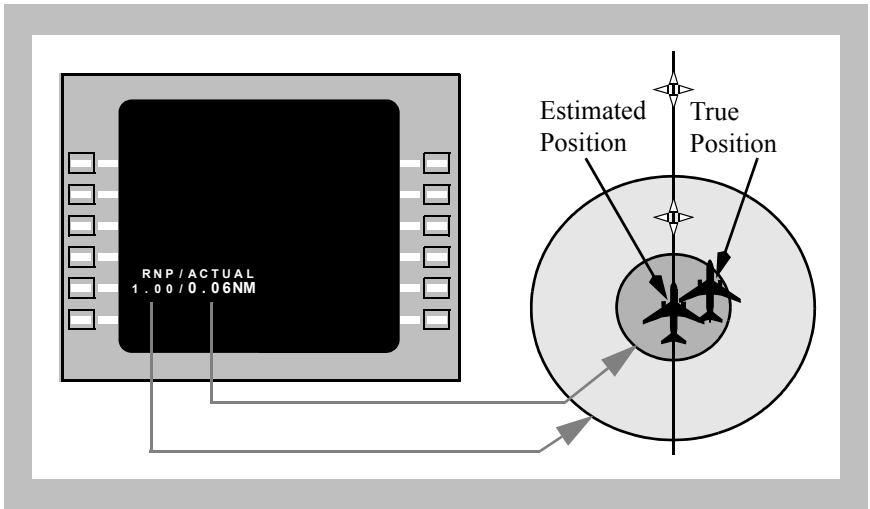
- USA and Canada - RNP 1.0 SIDs and STARs and
- Europe - P-RNAV (RNP 1.0).

RNAV approaches are compatible with all FMSs provided DME-DME or GPS updating is active at the beginning of the approach and the approach RNP is equal to or greater than the minimum demonstrated RNP in the AFM. Restrictions published on some RNAV approaches may preclude their use without GPS updating active. Approach RNP values can be as low as 0.30 NM.

For approaches, all Boeing FMSs have RNP 0.5 capability with DME-DME updating active without GPS updating. See the Approach section of this manual for further details regarding the techniques for flying RNAV approaches.

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ANP (Actual Navigation Performance) is the FMS calculated certainty of the aircraft's position in nautical miles. It is situation information for the flight crew representing a system estimate of the radius of the area in which the actual position of the aircraft lies. The system uses the best available sensor(s) to minimize positioning error. The flight crew or autoflight system must track the RNAV path using LNAV. There is a 95% probability that the aircraft is within the displayed ANP.



Basic RNP Concept

RNP is RNAV operations with on-board navigation performance monitoring and alerting. RNP was developed as a method for certifying the navigation capability for RNAV systems that can use multiple sensors for position updating. Navigation performance within the RNP level assures traffic and terrain separation. RNAV (RNP) procedures must be flown as published in the navigation database. Pilot defined routes and lateral or vertical route modifications are not allowed.

RNAV (RNP) AR (Authorization Required) procedures are RNP approaches that require special aircraft and aircrew authorization. For specific instructions refer to chapter 5, Instrument Approach - RNAV (RNP) AR.

The FMS uses one of the following as the displayed RNP:

- Default RNP - FMS default values are set by the FMS and are displayed if no RNP is available from the navigation database or one has not been manually entered.
- Navigation database RNP values (if available) are displayed based on values associated with the procedure. These values may be unique for certain segments or terminal procedures.
- Manually entered RNP - remains until changed or deleted.

The crew may need to make a manual RNP entry if the displayed RNP for the route or procedure is incorrect. Setting an RNP smaller than what is specified for the procedure, airspace, or route may cause nuisance crew alerts. If the RNP is set larger than that specified for a procedure or segment, crew alerting may occur at the incorrect RNP (if the specified RNP is exceeded). The RNP is depicted on the published procedure being flown.

Although today's airspace design has already established certain lateral limits (RNP), no Vertical Required Navigation Performance limits are published. Vertical Required Navigation Performance is available on some FMSs and may be used for certain descent profiles such as Continuous Descent Approaches (CDA), Optimized Profile Descents (OPD), or Tailored Arrivals (TAs).

The FMS calculates, monitors, and displays ANP as described in the Vol. 2. Crews should note that ANP is only related to the accuracy of FMS position.

Airplanes without Navigation Performance Scales (NPS)

For airplanes without NPS, the crew must refer to the FMS progress page for XTK and VTK information during the approach.

If a deviation occurs, and the correction back to course is not immediate, then the PM should refer to the FMS progress page and notify the PF if the maximum allowable deviations are reached.

Note: An excessive cross-track error does not result in a crew alert.

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During RNP operations other than approach, any time the deviation exceeds the limit, the crew may have to select a different autopilot roll or pitch mode or manually fly airplane back on course. If unable to comply the flight crew has to revert to other means of navigation such as conventional ground based or radar navigation.

During RNP approach operation, any time the deviation exceeds the limit the crew may change to a non-RNP procedure. If unable the crew should execute a missed approach unless suitable visual reference is already established. In the event of a missed approach, the crew may consider requesting an alternate clearance.

ANP Alerts

When ANP exceeds RNP, an UNABLE RNP EICAS alert is displayed. If this occurs during RNP operations other than approach, the crew should verify position, confirm updating is enabled, and consider requesting an alternate clearance. This may mean changing to a non-RNP procedure or route or changing to a procedure or route with a RNP higher than the displayed ANP value.

If the alert occurs during RNP approach operations, the crew should execute a missed approach unless suitable visual reference is already established. In the event of a missed approach, the crew may consider requesting an alternate non-RNP clearance.

Autoflight Use During RNP

Normally, a route segment or procedural leg is defined by its required width. For RNP operations, route width is normally equal to at least $2.0 \times \text{RNP}$ from either side of the LNAV course. Required width is determined by minimum terrain or traffic clearance requirements. The probability of exceeding this maximum deviation while in LNAV with the autopilot engaged is very small. These minimum values vary depending on LNAV, flight director and autopilot use, and whether GPS is the active source of position updating.

RNP operations require appropriate path tracking consistent with the RNP level. LNAV together with the flight director and the autopilot may be required for certain low RNP operations. Use of the autopilot and LNAV normally provide the required path tracking accuracy. During RNAV approaches using VNAV, VNAV PTH is required for any leg segment with a coded glide path angle. These procedures show only LNAV/VNAV approach minima and do not allow use of LNAV only. Use of the flight director alone may not provide sufficient guidance to maintain the path accurately.

Radius-to-Fix (RF) Legs

Note: The 747 is currently not capable of using any procedure that includes RF legs.

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. Some considerations regarding use of RF legs:

- There may be a maximum speed shown on some straight legs or some RF legs of smaller radius. This limitation is critical for the crew to observe since the ability of the AFDS to track the RF leg is determined by ground speed and maximum available bank angle. In high tailwinds, the resulting ground speed may cause the maximum bank angle to be reached. In this situation, excessive course deviation may occur if the maximum RF speed is exceeded.
- Do not begin a procedure by proceeding direct to an RF leg. This may cause excessive deviation when the aircraft maneuvers to join the RF leg. Normally there is a track-to-fix leg prior to an RF leg to ensure proper RF leg tracking.
- Intercept course to or direct to route modifications delete an RF leg if done to the second waypoint on an RF leg.
- If a go-around is executed while on an RF leg, it is important to immediately re-select LNAV to avoid excessive course deviation. GA roll mode is a track hold mode and is not compatible with low RNP operations if left engaged. The pilot flying must continue to track the LNAV course using the map display as a reference until LNAV is re-engaged.

If a temporary loss of the FMS occurs, RF legs will appear as part of the inactive route when the FMS returns to normal operation. Once the route is activated and the EXEC key is pressed, a normal LNAV capture of an RF leg is possible if the situation permits.

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 LNAV, VNAV, and instrument approaches using VNAV are some of the reduced workload features. 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, FLCH may be selected to continue the climb or descent 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.

Note: In the event the flight crew overrides the autopilot, the autopilot should be disengaged as soon as practical. Continued flight overriding the autopilot is not recommended.

Recommended Pitch and Roll Modes

If the LEGS page and map display reflect the proper sequence and altitudes, LNAV and VNAV are recommended. If LNAV is not used, use an appropriate roll mode. When VNAV is not used, the following modes are recommended:

FLCH has logic to allow shallow climbs and descents for small altitude changes. There is no need to use V/S mode for passenger comfort.

If unplanned speed or altitude restrictions are imposed during the arrival, the continued use of VNAV may induce an excessive workload. If this occurs, use FLCH or V/S as appropriate.

AFDS 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

Autothrottle use is recommended during all phases of flight. When in manual flight, autothrottle use is also recommended, however manual thrust control may be used to maintain pilot proficiency.

Manual Flight

The PM should make AFDS 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.

MCP Altitude Setting Techniques Using VNAV

When using VNAV for published instrument departures, arrivals, and approaches, 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 PTH in the descent or VNAV SPD in the climb will result in a risk of violating procedure altitude constraints.
- The potential to delete the next waypoint altitude constraint if the MCP altitude is beyond the next altitude constraint and altitude intervention is selected.

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 PTH or VNAV SPD, the MCP altitude must be set at the next altitude constraint.

AFDS Mode Control Panel Faults

In-flight events have occurred where various AFDS pitch or roll modes, such as LNAV, VNAV, or HDG SEL became un-selectable or ceased to function normally. Typically, these types of faults do not generate a failure annunciation. These faults may be caused by an MCP hardware (switch) problem.

If an AFDS anomaly is observed where individual pilot-selected AFDS modes are not responding normally to MCP switch selections, attempt to correct the problem by disengaging the autopilot and selecting both flight director switches to OFF. This clears all engaged AFDS modes. When an autopilot is re-engaged or a flight director switch is selected ON, the AFDS default pitch and roll modes should engage. The desired AFDS pitch and roll modes may then be selectable.

If this action does not correct the fault condition, the desired flight path can be maintained by selecting an alternate pitch or roll mode. Examples are included in the following table:

Inoperative or Faulty Autopilot Mode	Suggested Alternate Autopilot Mode or Crew Technique
HDG SEL or HDG HOLD	Set desired heading, disengage AFDS and manually roll wings level on the desired heading, and re-engage the AFDS. The AFDS will hold the established heading.
LNAV	Use HDG SEL to maintain the aircraft track on the magenta FMS course.
VNAV SPD or VNAV PTH (climb or descent)	Use FLCH or V/S. V/S should be selected for descent on final approach.
VNAV PTH (cruise)	Use altitude hold. If altitude hold is not directly selectable, use FLCH to automatically transition to altitude hold.
LOC	Use LNAV. Monitor and fly the approach referencing localizer raw data.
G/S	Use V/S or VNAV PTH to descend on an ILS approach. Monitor and fly the approach referencing glide slope raw data.

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 effect 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.

Refer to the Vol. 1, SP.16, Moderate to Heavy Rain, Hail, or Sleet procedure for more information.

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.

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

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, engine damage and airplane Total Air Temperature (TAT) probe icing.

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:

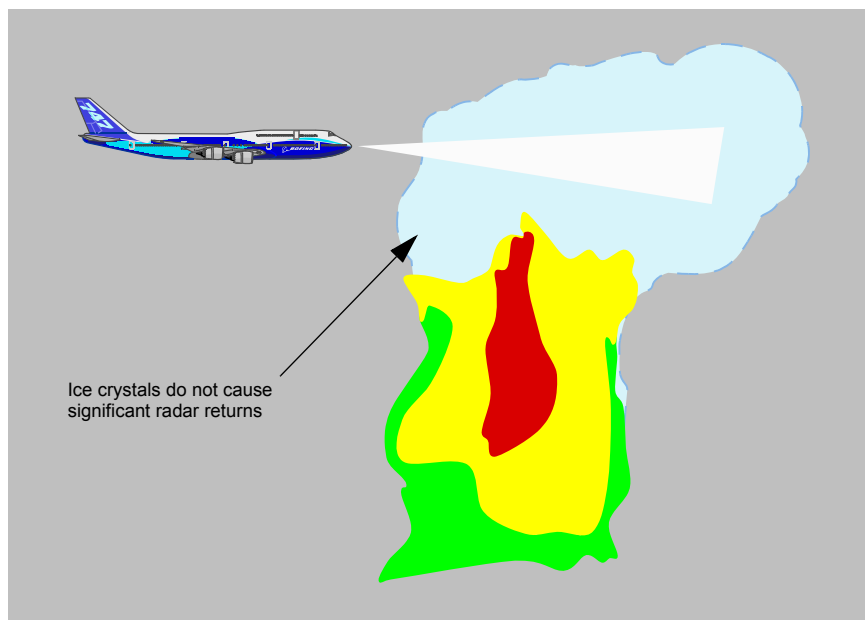
- appearance of rain on the windshield at temperatures too cold for liquid water to exist. This is due to ice crystals melting on the heated windows (sounds different than rain).
- airplane TAT indication remains near 0° C due to TAT probe icing
- areas of light to moderate turbulence
- In IMC with:
 - 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. The icing conditions detection system does not detect ice crystal icing. It is designed to detect supercooled water only.

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.

The airplane is capable of continued safe flight and landing in icing conditions in the event of an in-flight failure of the wing anti-ice system.



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Ground Operations
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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 during the pushback and towing process. 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 normally accomplished with all hydraulic systems pressurized and the nose wheel steering locked out.

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

Engine Start

Normal

Approximate Idle Indications

Standard day, sea level, approximate stabilized idle indications are:

- EPR - 1.00,
- N1 RPM - 22%,
- EGT - 320°C,
- N2 RPM - 63%,and
- fuel flow - 1400 PPH.

Normal Engine Start Considerations

- Advancing FUEL CONTROL switch to run prematurely can cause a hot start.
- Keep hand on FUEL CONTROL switch while observing RPM, EGT, and fuel flow until stabilized.
- If fuel is shutoff inadvertently (by moving FUEL CONTROL switch to CUTOFF) do not move FUEL CONTROL switch to RUN in an attempt to restart engine.
- Failure of ENGINE switch to remain engaged until starter cutout RPM is reached can result in a hot start.

Taxi

Taxi General

Loss of situational awareness and not following ATC instructions 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.
- Ensure both crewmembers understand the expected taxi route.
- Complex taxi clearances should be written down or entered into the CDU 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).

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.

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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

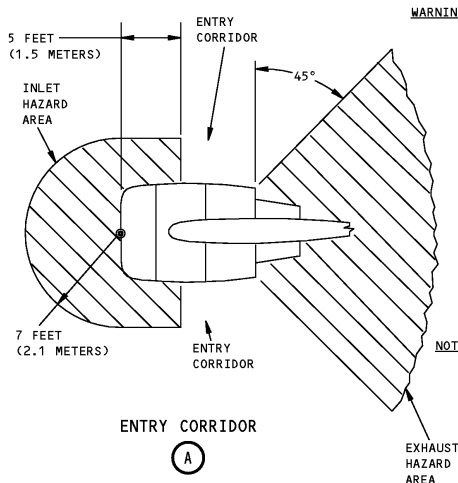
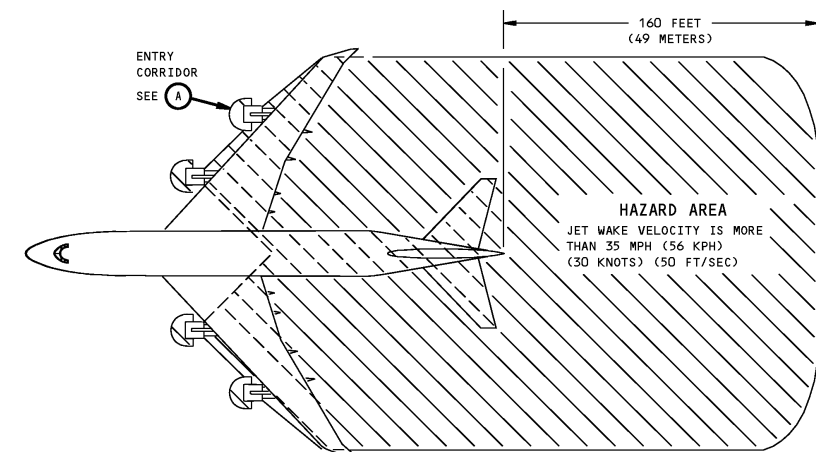
- Minimize distractions, such as heads down time, discretionary company and cabin communications, engine starts and checklists when on any runway.
- Runways are typically wider than taxiways. As a result of field of vision, signs located at the edge of a runway may be more difficult for the pilot to 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 thrust lever movement is slow, particularly at high gross weights. Engine noise level in the flight deck is low and not indicative of thrust output.

Excess thrust while taxiing may cause foreign objects to deflect into the lower aft fuselage, stabilizer, or elevators, especially when the engines are over an unimproved surface. Run-ups and taxi operations should only be conducted over well maintained paved surfaces and runways.

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 45% N1 is necessary, ensure area behind aircraft is clear.



WARNING: KEEP ALL PERSONS OUT OF THE DANGEROUS AREA DURING ENGINE OPERATION. IF THE SURFACE WIND IS MORE THAN 25 KNOTS, INCREASE THE DANGEROUS AREA AT THE ENGINE INLET BY 20 PERCENT.

CLEAN THE RAMP IF THERE IS SNOW, ICE, WATER, OIL OR OTHER CONTAMINATION, OR MOVE THE AIRPLANE TO A LOCATION THAT IS CLEAN.

MAKE SURE THAT ALL PERSONS ARE SAFE BEFORE YOU START THE ENGINE.

MAKE SURE THE PERSONS IN THE FLIGHT COMPARTMENT CAN SPEAK TO ALL PERSONS NEAR THE DANGEROUS AREA DURING ENGINE OPERATION.

OBEY ALL OF THE GROUND SAFETY PRECAUTIONS FOR THE ENGINES.

THE ENGINES CAN PULL PERSONS OR UNWANTED MATERIALS INTO THEM AND CAUSE INJURIES TO PERSONS OR DAMAGE TO EQUIPMENT.

NOTE: THE DANGEROUS AREA "A" IS SHOWN FOR ONE ENGINE ONLY. THE DANGEROUS AREA AROUND EACH ENGINE HAS THE SAME DIMENSIONS. WHEN YOU OPERATE TWO OR MORE ENGINES, THE DANGEROUS AREA IS THE COMBINATION OF THE DANGEROUS AREAS OF ALL THE OPERATING ENGINES.

FORWARD THRUST AT MINIMUM IDLE POWER - COWLING CLOSED

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Engine Out Taxi

High bypass engines require warm up prior to applying takeoff thrust and cool down prior to shutting down. 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.

Note: If the captain elects to shutdown engine number 3 for taxi in, caution must be exercised in the ramp area due to excessive jet blast. Engine out taxi should not be attempted in the ramp area if high thrust settings will be required.

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 engines 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 all engines operating.

Taxi Speed and Braking

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.

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 tiller 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. 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: If reverse thrust is selected after V speeds have been entered, the V speeds are removed from the airspeed display, and full TO thrust becomes the thrust limit takeoff.

Note: High taxi speed combined with heavy gross weight and a long taxi distance can result in tire sidewall overheating. At maximum weights with taxiing distances greater than 15,000 feet (4575 m), use 20 knots as maximum taxi speed.

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

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.

Antiskid Inoperative

With antiskid inoperative, tire damage or blowouts can occur if moderate to heavy braking is used. With this condition, it is recommended that taxi speed be adjusted to allow for very light braking.



Tiller/Rudder Pedal Steering

The captain's and first officer's positions are equipped with a nose wheel steering tiller. The nose wheel steering tiller 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 tiller 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 notch formed by the rise in the glare shield, just to the left of the master warning light.

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.

Body Gear Steering

Body gear steering provides shorter turn radius, reduces thrust requirements for tight turns, and minimizes tire scrubbing. It is automatically activated when the nose gear steering angle exceeds 20° and taxi speed is below approximately 20 knots.

Body gear steering operation is especially important at heavy weights where stress may be applied to wheels and tires. Excessive tire scrubbing and tire slippage can result from taxiing under these conditions with body gear steering inoperative.

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.

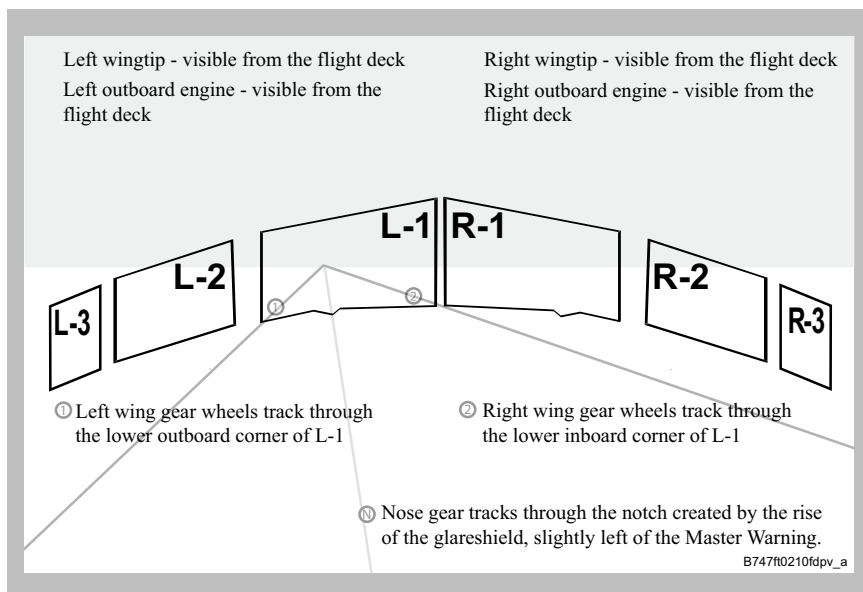
During taxiing, the pilot's heels should be on the floor, sliding the feet up on the rudder pedals only when required to apply brakes to slow the taxi speed, or when maneuvering in close quarters on the parking ramp.

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.

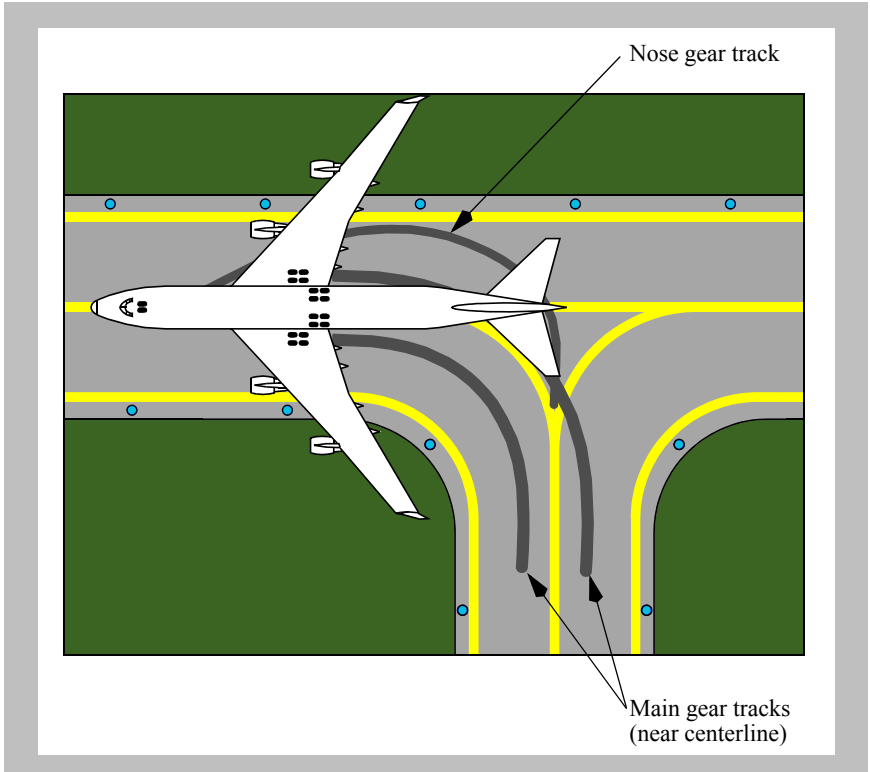
Captain's Perspective



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 forward of the nose wheels and main gear as indicated in the tables in this chapter.

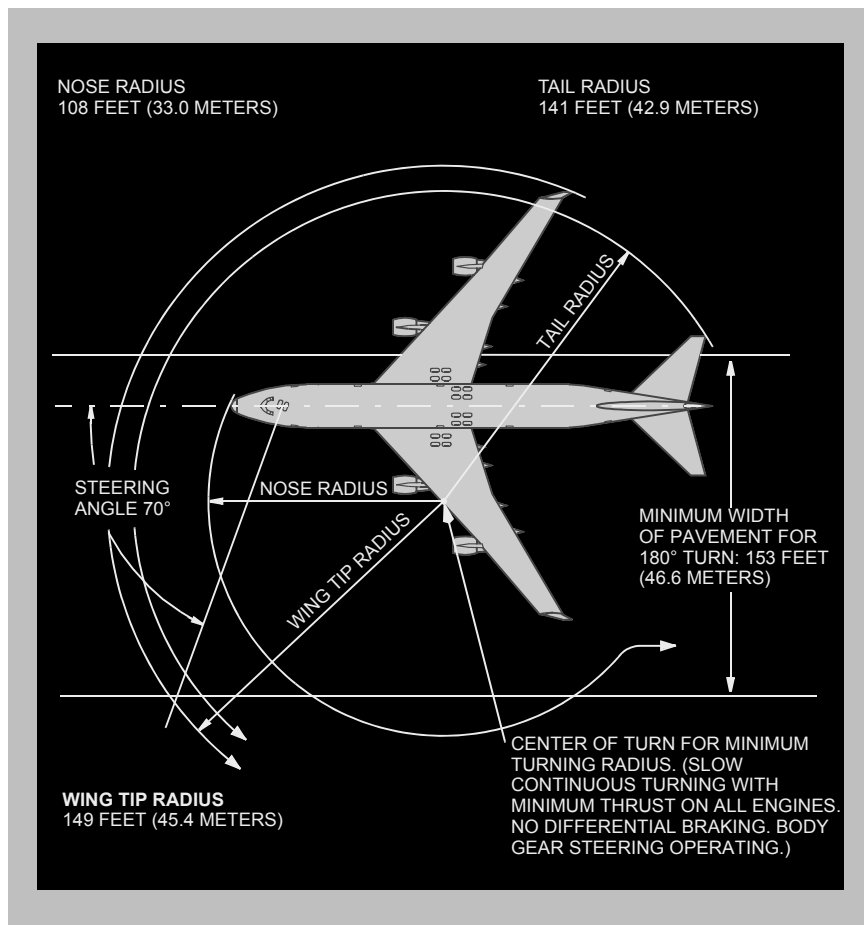
As the following diagram illustrates, while the aircraft is turning, the main gear tracks inside the nose gear. The smaller the radius of the turn, the greater the distance that the main gear tracks inside the nose gear and the greater the need to steer the nose gear outside of the taxi path (oversteer).



Turning Radius Diagrams

The following illustrations show the minimum turn radius capability. The tip of the winglet swings the largest arc while turning and determines the minimum obstruction clearance path. All other portions of the aircraft are within this arc. It should be noted from the illustration that the wing tips travel outboard about 12 feet and travel 37 feet in front of the nose.

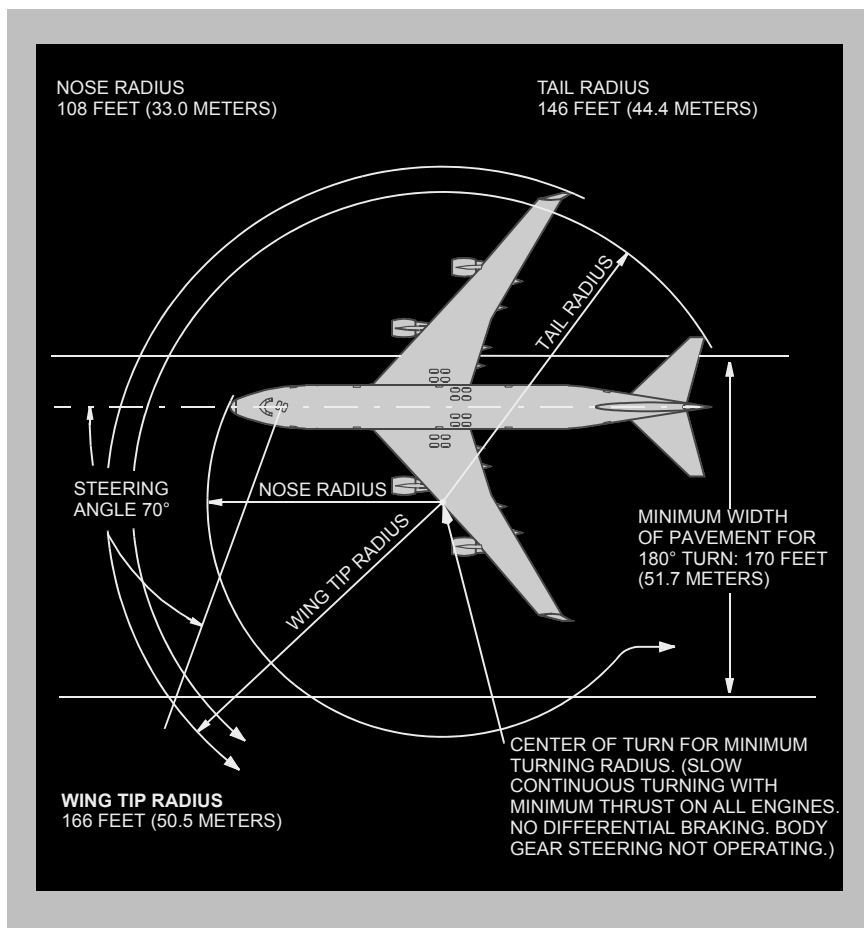
Body Gear Steering Activated



CAUTION: Do not attempt to make a turn away from an obstacle within 12 feet of the wing tip or within 37 feet of the nose.

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Body Gear Steering Deactivated



CAUTION: Do not attempt to make a turn away from an obstacle within 11 feet of the wingtip or within 59 feet of the flight deck. Avoid use of excessive thrust in ramp area due to possible damage or injury from jet blast.



Visual Cues and Techniques for Turning while Taxiing

The following visual cues assume the pilot’s seat is adjusted for optimum eye position. The following techniques also assume a typical taxiway width. 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 wheel steering tiller required for each turn. Except for turns less than approximately 30°, speed should be 10 knots or less prior to turn entry. For all turns, keep in mind the main gear are located behind the nose wheels, which causes them to track inside the nose wheels during turns. The pilot position being forward of the nose wheels and main gear is depicted in the table below.

Model	Pilot Seat Position (forward of nose gear) feet (meters)	Pilot Seat Position (forward of main gear) feet (meters)
747 - 400	7.25 (2.2)	96 (29.3)

Turns less than 90 degrees

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 degrees or more

Initiate the turn as the intersecting taxiway centerline (or intended exit point) approaches the aft edge of the middle side window. Initially use approximately full nose wheel steering tiller displacement. Adjust the tiller 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 wing gear are clear of the inside radius, gradually release the tiller input as the aircraft lines up with the intersecting taxiway centerline or intended taxi path.

Turns of 180 Degrees

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, etc.), 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.

Note: Be cautious when required to make a 180° turn as many airports have runways that are only 150 feet wide.

Approach the edge of the taxi surface at a shallow angle until the outboard side of the wing gear wheels are near the edge. The lower outboard corner of the pilot's forward window is a good visual reference for the outboard side of the wing gear wheels on the same side. The lower inboard corner of the pilot's forward window is also a good reference for the opposite side wing gear wheels.

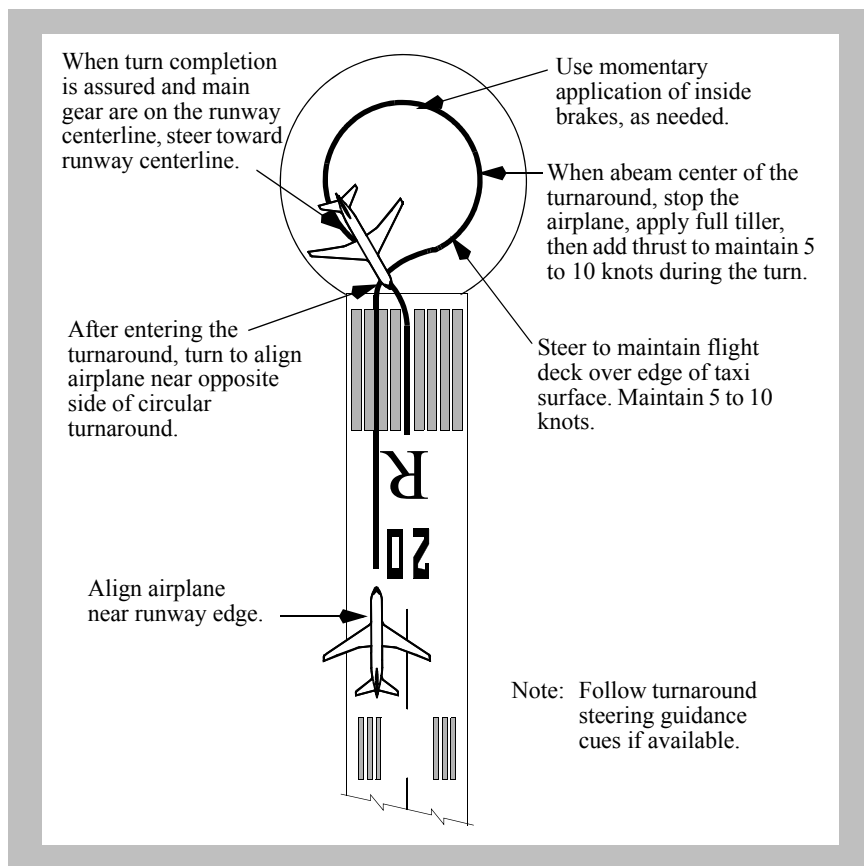
Note: Painted runway markings are slippery when wet and may cause skidding of the nose gear during the turn.

Turning radius can be reduced by following a few specific taxi techniques. Taxi the aircraft so that the wing 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 tiller to the maximum steering angle, release the brakes, then add thrust on the outboard side. Only use the engines 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 tiller 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.

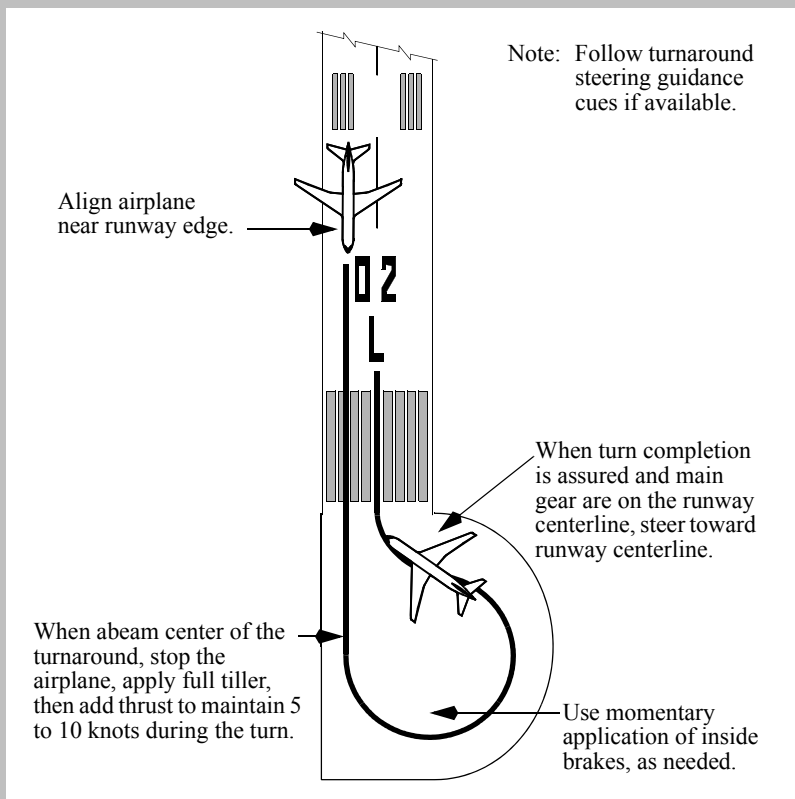
The following diagrams show suggested aircraft ground tracks for minimum radius 180° turns with various runway turnaround configurations. These ground tracks provide the best maneuver capability while providing the maximum runway length available for takeoff at the completion of the turn.

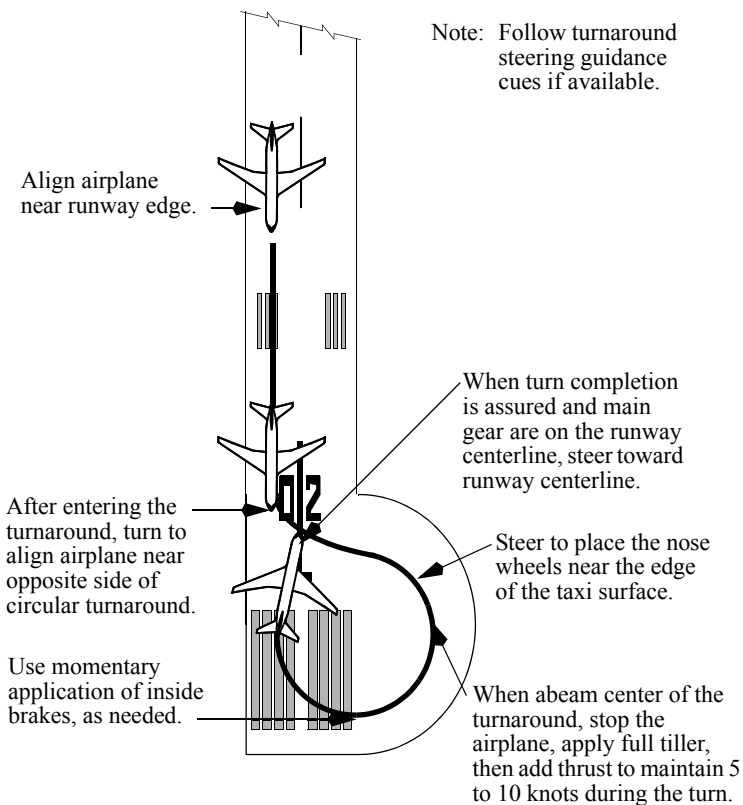
Techniques when using a Circular Turnaround



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Techniques when using a Hammerhead Turnaround

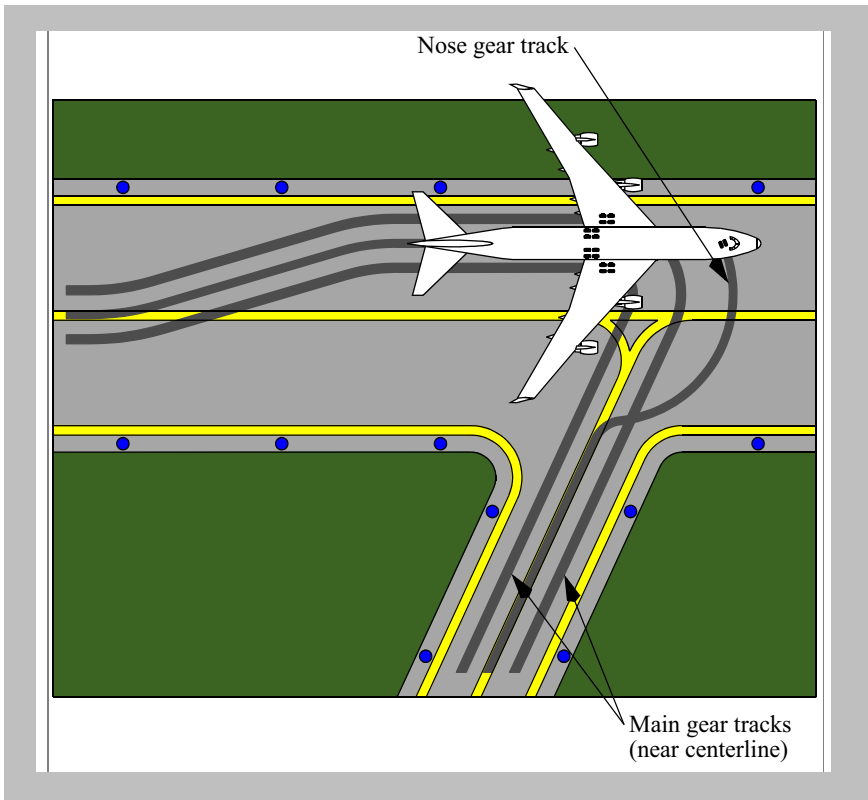


Techniques when using a Hammerhead Turnaround

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, engine clearance, and the possibility of FOD ingestion on the side of the aircraft that may be displaced over an unpaved surface.



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 all 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.

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.

Ground De/Anti-Icing

Definitions and Concepts

Ground de/anti-icing background information and policies are described in this section. 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.

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.

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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; and
- radome.

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, and
- 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.

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.

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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.

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.

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.

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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.

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.

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.

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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.

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.

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.

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 airstart 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.

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 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.

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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;
- 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.

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.

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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.

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).

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.
- 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.

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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.

-
- 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.

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

Fluid Used to Anti-Ice	Active Precipitation					
	Frost	Freezing Fog	Snow, Snow Grains, Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wings
Type I	Accomplish one of the following actions: A Cabin Check, An External Check, or Additional De/Anti-Icing			Takeoff Not Authorized		
Type II or Type IV				Accomplish one of the following actions: An External Check, or Additional De/Anti-Icing		

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.

Takeoff and Initial Climb

Chapter 3

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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.

The PF normally displays the takeoff reference page on the CDU. Display of the takeoff reference page allows the crew to have immediate access to V-speeds during takeoff in the event that V-speeds are inadvertently removed from the airspeed display. After changes to the takeoff briefing have been updated during the Before Takeoff procedure, the PF may elect to display the CLB page for takeoff. However, 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. The PM normally displays the LEGS page during takeoff and departure to allow timely route modification if necessary.

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

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 tiller is released and apply takeoff thrust by advancing the thrust levers to approximately 1.1 EPR. Allow the engines to stabilize momentarily then promptly advance the thrust levers to takeoff thrust. The TO/GA switch must be pushed prior to 50 KIAS to engage the autothrottle. Above 50 KIAS, autothrottle engagement is inhibited until the aircraft is above 400 feet AGL. In the unlikely event that autothrust does not engage when the TO/GA switch is pressed during takeoff, manually set takeoff thrust to the target thrust setting prior to 80 knots.

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 stabilized at or above 50% N1.

Ensure the nose wheel steering tiller is released, then gently release the brakes and promptly advance the thrust levers to takeoff thrust (autothrottle TO/GA).

All Takeoffs

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 thrust levers 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 thrust levers to takeoff thrust may adversely affect takeoff distance.

The TO/GA switch should be pushed immediately after the engines have stabilized. This will engage the autothrottle and will advance the thrust levers to the takeoff thrust setting.

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

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

Ensure the target EPR is set by 80 knots. Minor increases in thrust may be made immediately after 80 knots. After takeoff thrust is set, a small deviation in EPR 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 thrust settings, runway conditions, etc., it is not practical to specify a precise tolerance for EPR differences between the engines.

The HOLD mode protects against thrust lever movement if a system fault occurs. Lack of the HOLD annunciation means the protective feature may not be active. If HOLD annunciation does not appear, no crew action is required unless a subsequent system fault causes unwanted thrust lever 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 thrust levers until V1 in order to respond quickly to a rejected takeoff condition. After V1, the captain's hand should be removed from the thrust levers.

The PM should monitor engine instruments and airspeed indications during the takeoff roll and announce any abnormalities. The PM should announce passing 80 knots and the PF should verify that his airspeed indicator is in agreement.

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.

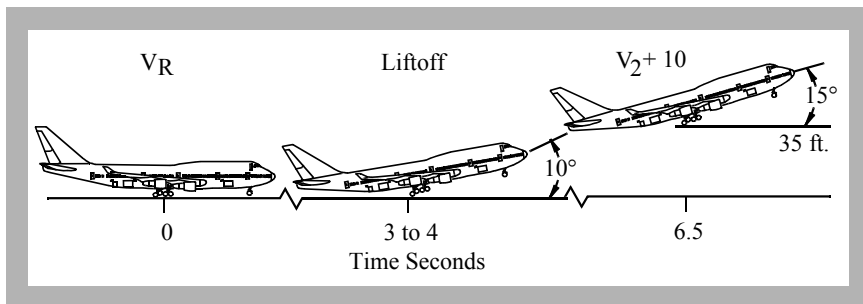
Above 80 knots, relax the forward control column pressure to the neutral position. For optimum takeoff and initial climb performance, initiate a smooth continuous rotation at VR toward 15° of pitch attitude. However, takeoffs at low thrust setting (low excess energy) will result in a lower initial pitch attitude target to achieve the desired climb speed. The use of stabilizer trim during rotation is not recommended. 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.

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

Using the technique above, resultant rotation rate is approximately 2.5° per second. Liftoff attitude is achieved in approximately 3 to 5 seconds depending on aircraft weight and thrust setting.

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.

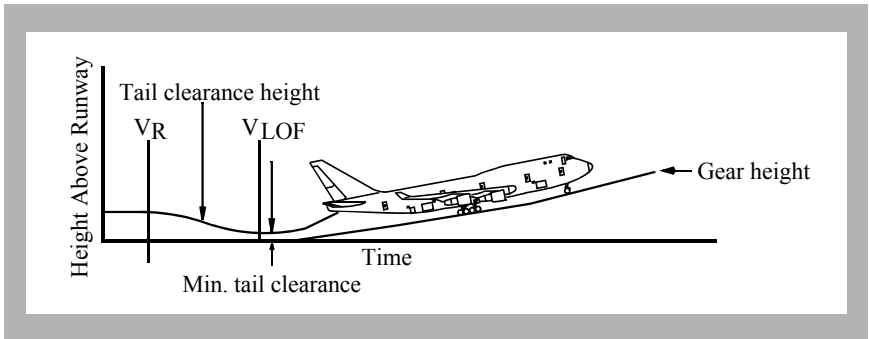
Note: When operating at low gross weights, takeoff with less than full rated thrust will aid in aircraft directional control in the event of an engine failure. The rotation should be accomplished at the normal rate, but the pitch attitudes during the transition to initial climb may be higher than normal.



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Typical Takeoff Tail Clearance

The following diagram and table show the effect of flap position on liftoff pitch attitude and minimum tail clearance during takeoff. Additionally, the last column of the table shows the pitch attitude for tail contact with wheels on the runway and landing gear struts extended. For a discussion of tail strike procedures see this chapter and the Tail Strike NNC.



Model	Flaps	Liftoff Attitude (degrees)	Minimum Tail Clearance inches (cm)	Tail Strike Pitch Attitude (degrees)
747-400	10	10.1	39 (99)	12.5
	20	10.0	40 (102)	12.5

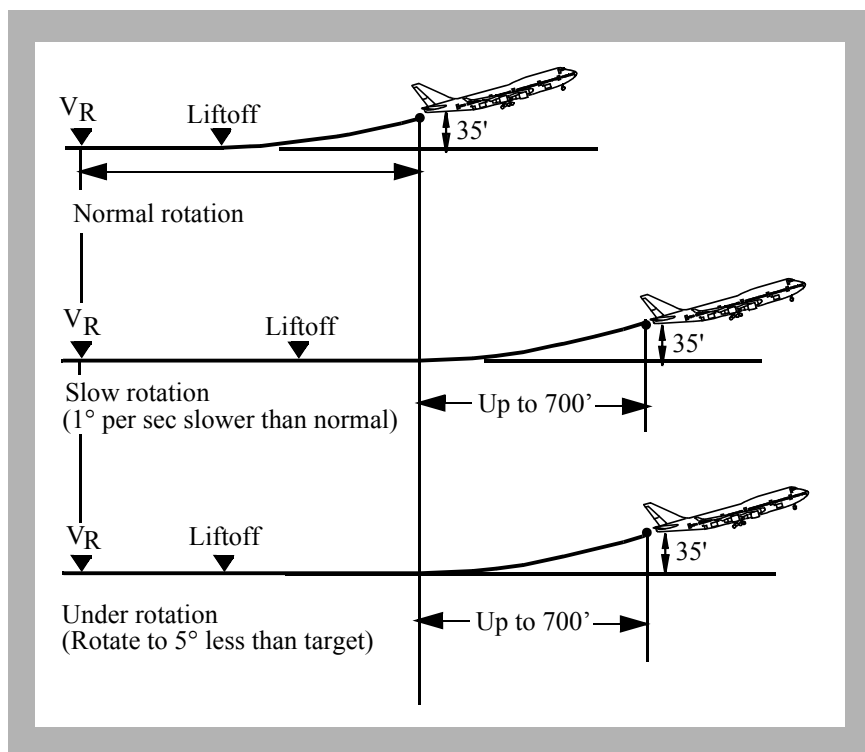
Effect of Rotation Speed and Pitch Rate on Liftoff

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.

An improper rotation can have an effect on the command speed after liftoff. If the rotation is delayed beyond $V_2 + 10$, the speed commanded by the flight director is rotation speed up to a maximum of $V_2 + 25$. An earlier liftoff does not affect the commanded initial climb speed. However, either case degrades overall takeoff performance.

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.

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

Note: Elevator forces for rotation are very nearly the same for all weights and CG locations.



Crosswind Takeoff

Engine surge can occur with a strong crosswind or tailwind component if takeoff thrust is set before brake release. Therefore, the rolling or static takeoff procedure is strongly advised when crosswinds exceed 20 knots or tailwinds exceed 10 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. Large control wheel inputs can have an adverse effect on directional control near VMCG due to the additional drag of the extended spoilers.

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 approximately centered. Throughout the takeoff roll, gradually increase control wheel displacement 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.

Gusty Wind and Strong Crosswind Conditions

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.

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 Full Power)

Normally, takeoffs are conducted with less than full rated 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), derated takeoff thrust (fixed derate), or a combination of these two methods. Takeoff with less than full rated takeoff thrust using any of these methods 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. Regardless of the method, use the takeoff speeds provided on the WDR corresponding to the specific thrust setting being used.

Note: Takeoff with full rated takeoff thrust is recommended if windshear conditions are suspected, unless the use of a fixed derate is required to meet a dispatch performance requirement.



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, or
- an ATM thrust setting is not authorized by the WDR.

ATM is achieved by selecting an assumed temperature higher than the actual ambient temperature.

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 full rated takeoff thrust. At any time during takeoff, thrust levers may be advanced to the full rated 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.

Note: For ATM takeoffs, slightly more back pressure may be needed during rotation and initial climb.

Derated Takeoff Thrust (Fixed Derate)

Derated takeoff thrust (fixed derate) is a certified takeoff thrust rating lower than full rated takeoff thrust. In order to use derated takeoff thrust, takeoff performance data for the specific fixed derate level is required. Derated takeoff thrust is obtained by selection of TO1 or TO2 in the FMS.

When using derated takeoff thrust, the takeoff thrust setting is considered a takeoff operating limit since minimum control speeds (VMCG and VMCA) and stabilizer trim setting are based on the derated takeoff thrust.

Thrust levers should not be advanced unless conditions are encountered during the takeoff where additional thrust is needed on all engines, such as a windshear condition. If an engine failure occurs during takeoff, any thrust increase beyond the fixed derate limit could result in loss of directional control.

Note: Derated takeoff thrust (fixed derate) may be used for takeoff on a wet runway and on a runway contaminated with standing water, slush, snow, or ice.

Derated takeoff thrust (fixed derate) may permit a higher takeoff weight when performance is limited by VMCG, such as on a runway contaminated with standing water, slush, snow, or ice. This is because derated takeoff thrust allows a lower VMCG.

Combination ATM and Fixed Derate

Note: All limitations and restrictions for ATM and derated takeoff thrust (fixed derate) must be observed.

ATM and derated takeoff thrust (fixed derate) may be combined by first selecting a fixed derate and then an assumed temperature higher than the actual ambient temperature. Although the takeoff thrust setting is not considered a takeoff operating limit for the ATM thrust reduction, the selected fixed derate is still considered a takeoff operating limit since takeoff speeds consider VMCG and VMCA only at the fixed derate level of thrust.

Since the crew has no indication of the fixed derate limit, thrust levers should not be advanced unless conditions are encountered during the takeoff where additional thrust is needed on all engines, such as a windshear condition. If an engine failure occurs during takeoff, any thrust increase beyond the fixed derate limit could result in loss of directional control.

Thrust Control

When conducting an ATM takeoff, if more thrust is needed (up to maximum thrust) when thrust is in HOLD mode, thrust levers 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 thrust levers to maximum thrust.

When conducting a derated thrust (fixed derate) takeoff or a takeoff with a combination ATM and fixed derate, takeoff speeds consider VMCG and VMCA only at the fixed derate level of thrust. Thrust levers should not be advanced beyond the fixed derate limit unless conditions are encountered during the takeoff where additional thrust is needed on all engines, such as a windshear condition. If an engine failure occurs during takeoff, any thrust increase beyond the fixed derate limit could result in loss of directional control.

When combining a high level of derate with a high assumed temperature, or if a climb thrust rating higher than the automatically selected climb thrust rating is selected, it is possible that the climb thrust may be higher than the takeoff thrust. In such case, thrust levers will advance forward upon reaching thrust reduction altitude.

If more thrust is needed (up to maximum thrust) when the aircraft is on the ground and HOLD mode is displayed, the thrust levers must be manually advanced.

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After the aircraft is in the air, pushing a TO/GA switch advances the thrust levers to maximum available thrust and THR REF is annunciated.

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.

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. Takeoff operations with reduced thrust (ATM or fixed derate) are permitted provided takeoff performance accounts for the runway surface condition. Snow (wet or dry), slush, dry snow, standing water, and ice will adversely affect takeoff performance. Slush 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 Takeoff on Contaminated Runways or Landing with Braking Action Less than Good, 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.

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 and, if required, slight differential thrust.

Forward pressure on the control column during the initial portion of the takeoff roll (below approximately 80 knots) increases nose wheel steering effectiveness.

Note: On very slippery runways, overcontrol of the rudder pedal during initial acceleration can quickly destabilize directional control.

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 Takeoff on Contaminated Runways or Landing with Braking Action Less than Good.

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)

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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.

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. AWABS presents customized V-speeds on the WDR. The V₁ may be reduced from the balanced V₁ to give improved stopping margins on wet or contaminated runways. When the CLW is limiting but the RATOW provides significant performance margin the V-speeds may be increased to improve climb performance and thereby increase the Climb Limit Weight. Note that the balanced V₂ is generally less than the speed for best angle of climb, so increasing V₂ by a few knots can improve the climb angle or gradient.

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). Effects of improper RTO execution are shown in the diagrams located in the RTO Execution Operational Margins section, this chapter. 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.

There have been incidents where pilots have missed FMS alerting messages informing them that the takeoff speeds have been deleted or they have forgotten to set the airspeed bugs. If, during a takeoff, the crew discovers that the V speeds are not displayed and there are no other fault indications, the takeoff may be continued. The lack of displayed V speeds with no other fault indications does not fit any of the published criteria for rejecting a takeoff. In the absence of displayed V speeds, the PM should announce V1 and VR speeds to the PF at the appropriate times during the takeoff roll. The V2 speed should be displayed on the MCP and primary airspeed indicators. If neither pilot recalls the correct rotation speed, rotate the aircraft 5 to 10 knots before the displayed V2 speed.



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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 Escape Hatch opens	X		
Windshear encounter*	X		
Engine failure	X	X	
Fire or fire warning	X	X	
If the airplane 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.”



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

During a rejected takeoff with RTO selected, below 85 knots ground speed, use manual braking. Above 85 knots ground speed, RTO 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, simultaneously: • Close thrust levers. • Disengage Autothrottles. • Verify the operation of RTO autobrakes if available. Note: If RTO autobrakes are selected, monitor performance and apply manual wheel brakes if deceleration is not adequate.	Verify actions as follows: • Thrust levers closed. • Autothrottles disengaged. • Maximum brakes applied.
Apply maximum reverse thrust consistent with conditions.	Verify reverse thrust applied.
Verify operation of speedbrakes. Extend speedbrakes if not deployed.	If SPEEDBRAKE deployed, call "SPEEDBRAKES UP". If SPEEDBRAKES not deployed, call "NO SPEEDBRAKES"
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 reverse thrust 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.

Note: The captain has the option to manually deploy the speedbrakes prior to thrust reverser actuation.



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 and 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 the critical engine at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.

Part 1 defines the critical engine as “the engine whose failure would most adversely affect the performance or handling qualities of an aircraft.”

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. See RTO Execution Operational Margins diagrams for the consequences of initiating a reject after V1 and/or using improper procedures.

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 25 to 30 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.

RTO Execution Operational Margins

A successful rejected takeoff at or near V1 is dependent upon the captain making timely decisions and using the proper procedures.

The data in the following diagrams, extracted from the Takeoff Safety Training Aid, are provided as a reference. The individual diagrams show the approximate effects of various configuration items and procedural variations on the stopping performance of the aircraft. These calculations are frequently based on estimated data and are intended for training discussion purposes only. The data are generally typical of the aircraft at heavy weights, and except as noted otherwise, are based on the certified transition time.

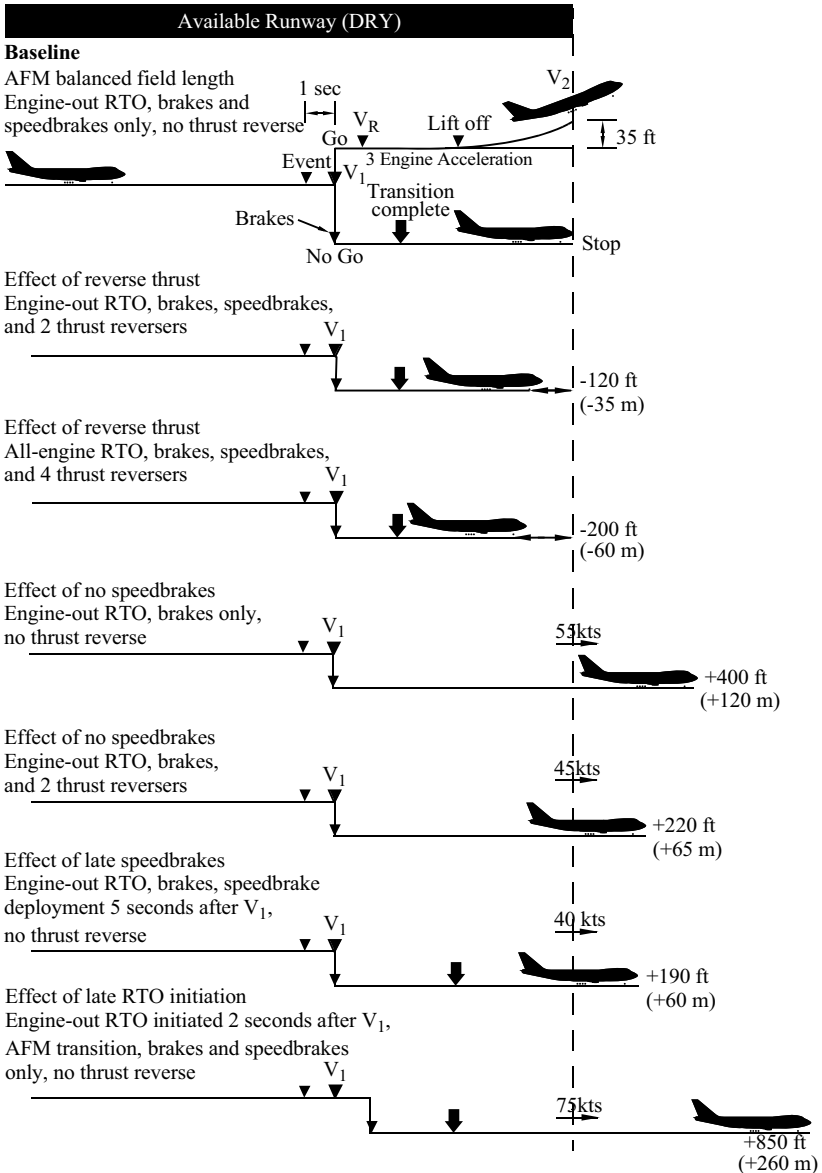
Each condition is compared to the baseline condition. The estimated speed at the end of the runway and the estimated overrun distance are indicated at the right edge of each figure. The distance estimates assume an overrun area that can produce the same braking forces as the respective runway surface. If less than the baseline FAA accelerate-stop distance is required, the distance is denoted as a negative number.



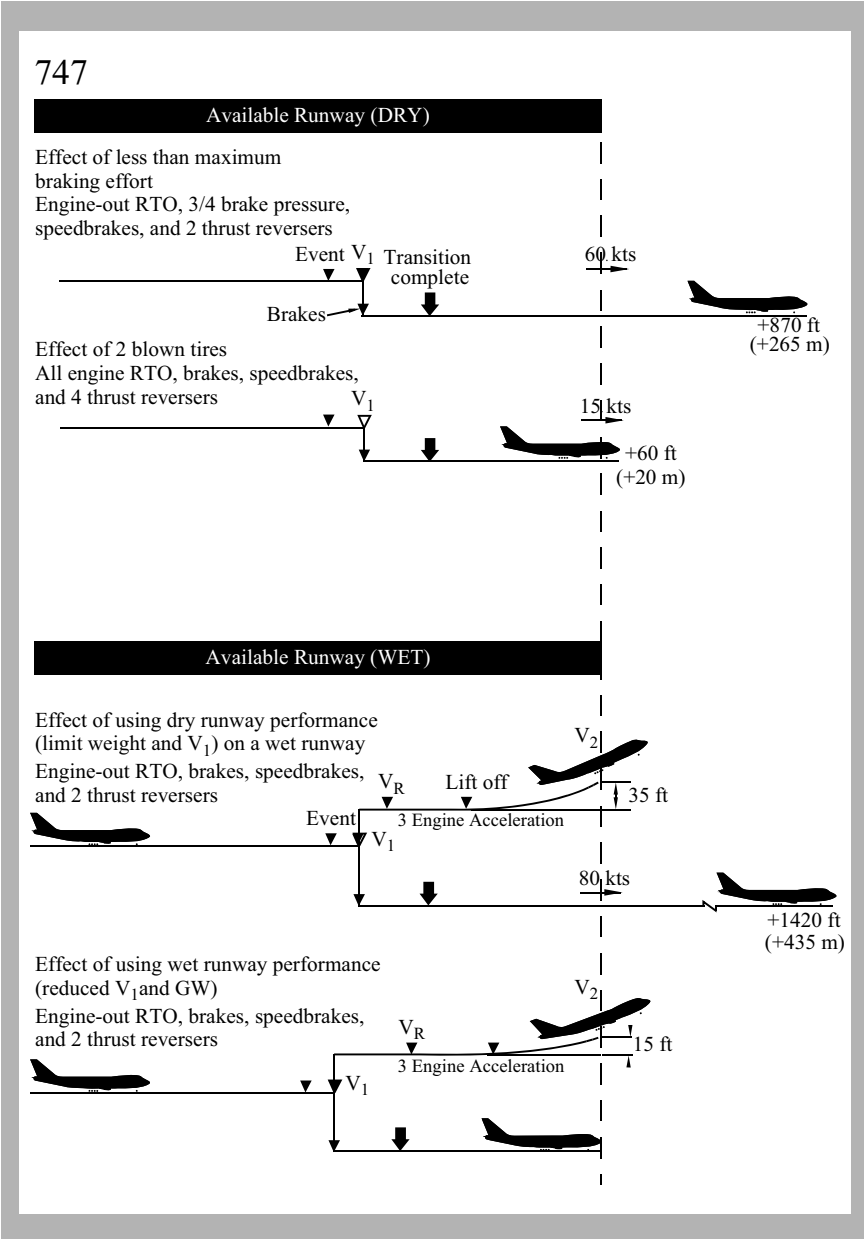
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RTO Execution Operational Margins

747



RTO Execution Operational Margins





Tail Strike

CAUTION: Do not apply abrupt nose up inputs just before or immediately following liftoff. The tail will strike the runway at 12.5° pitch attitude with main wheels on the runway and the landing gear struts extended.

CAUTION: If the flight directors are selected ON for takeoff, do not follow the flight director commands until after liftoff and clear of the runway. Current flight director logic is not intended to command the appropriate rotation rate and initial pitch attitude.

CAUTION: Proper rotation is essential to attain the required performance from the aircraft. Early rotation, excessive rotation rates, or over-rotation decreases the clearance between the tail of the aircraft and the runway surface and may cause the tail to strike the runway. Further, excessive rotation rates cause excessive engine wear and possible fan blade damage. Late, slow, or improper rotation decreases initial climb performance.

Tail strike occurs when the lower aft fuselage 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.

Note: Anytime fuselage contact is suspected or known to have occurred, accomplish the appropriate NNC.

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). In addition, sometimes accurate information is either entered incorrectly in the flight management system (FMS) or set incorrectly on the 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 15°. However, an aggressive rotation into the pitch bar at takeoff is not appropriate and can cause a tail strike.

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 $V_2 + 10$ to 25 knots until another pitch mode is engaged.

$V_2 + 10$ 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 $V_2 + 10$ knots during the initial climb, stop the acceleration but do not attempt to reduce airspeed to $V_2 + 10$ knots. Any speed between $V_2 + 10$ and $V_2 + 25$ knots results in approximately the same takeoff profile. Crosscheck indicated airspeed for proper initial climb speed.



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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.

Note: On very short flights this fuel quantity may not be enough to prevent forward fuel pump low pressure lights from illuminating after takeoff. Therefore, the minimum dispatch fuel has been set at 50,000 lbs. This fuel quantity should prevent forward fuel pump low pressure lights from illuminating after takeoff. If any main tank fuel pump indicates low pressure do not turn off fuel pump switches. Avoid rapid acceleration of the aircraft, reduce nose-up body attitude, and maintain minimum nose-up body angle required for a safe climb gradient.

Immediate Turn after Takeoff - All Engines

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 maintain $V_2 + 10$ to $V_2 + 25$ knots with takeoff flaps.

Note: A maximum bank angle of 25° is permitted at $V_2 + 10$ knots with takeoff flaps.

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 LNAV (if not armed before takeoff) after passing 400 feet AGL. If LNAV is armed for takeoff, it engages above 50 feet AGL and within 2.5 NM of the active leg. 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 AGL to intercept the desired track for LNAV capture. When the departure procedure is not a part of the active flight plan, use HDG SEL or HDG HOLD mode. When an immediate turn after takeoff is necessary, the desired heading may be preset before takeoff.

Nav aids and appropriate radials or tracks required for use during the departure may be displayed on the navigation display using the FIX page feature and/or VOR/ADF switches on the EFIS control panel. Use of the STA and WPT switches on the EFIS control panel provides additional information on the navigation display.

Pitch Modes

VNAV, armed on the ground with the appropriate acceleration altitude entered, is the recommended pitch mode for takeoff. When armed for takeoff, VNAV engages at 400 feet AGL and provides AFDS management for acceleration, flap retraction, and climb out. The VNAV profile and acceleration schedule is compatible with most planned departures.

Note: Climb thrust is normally selected automatically by programming the FMS so that VNAV commands climb thrust after flaps retract to 5.

With VNAV engaged, an acceleration is automatically commanded. Retract flaps on schedule. Check that the thrust reference changes from TO to CLB on the EICAS at the point selected on the TAKEOFF REF page. If VNAV is not used, at acceleration height select FLCH and set the command speed to flaps up maneuvering speed + 20 knots. Climb thrust is normally set after flaps retract to 5 using the THR switch on the MCP. Check that the thrust reference changes from TO to CLB on the EICAS.

Autopilot Engagement

The minimum altitude for autopilot engagement is 250 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

The minimum altitude for flap retraction is 400 feet.

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.



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During flap retraction, selection of the next flap position is initiated when reaching the maneuver speed for the next flap position. The maneuver speed for the existing flap position is indicated by the numbered flap maneuver speed bugs on the airspeed display. The flap retraction schedule for the 747 differs from other Boeing models because the flaps are not retracted until the maneuver speed for the next flap position is reached. For example, flaps 5 is selected after reaching flaps 5 maneuver speed. During flap retraction, full maneuver capability or at least 40° of bank (25° of bank plus a 15° overshoot) to stick shaker is provided while retracting the flaps through flaps 1. At 680,000 lbs and below, full maneuver capability exists with flaps up and at flaps up maneuver speed (UP). However, above 680,000 lbs full maneuver capability does not exist until reaching UP + 20 knots. For this reason, limit bank angle to 15 with flaps up until reaching UP + 20 knots.

Note: To achieve optimum climb performance during flap retraction, accelerate while climbing so thrust can be reduced to the climb limit within 5 minutes.

Note: Consider delaying flap retraction while maneuvering, heavy weight or in turbulence. Maintain airspeed above the top of the minimum maneuver speed amber band on the PFD speed tape to ensure full maneuver margin capability. If airspeed drops into the amber band the aircraft maneuver capability and margin to stick shaker are reduced. At heavy weights, delaying flap retraction may result in speeds approaching flap placard limits. Prevent flap overspeeds by monitoring flap placard speeds, PFD maximum speed (red zipper) and AFDS pitch guidance.

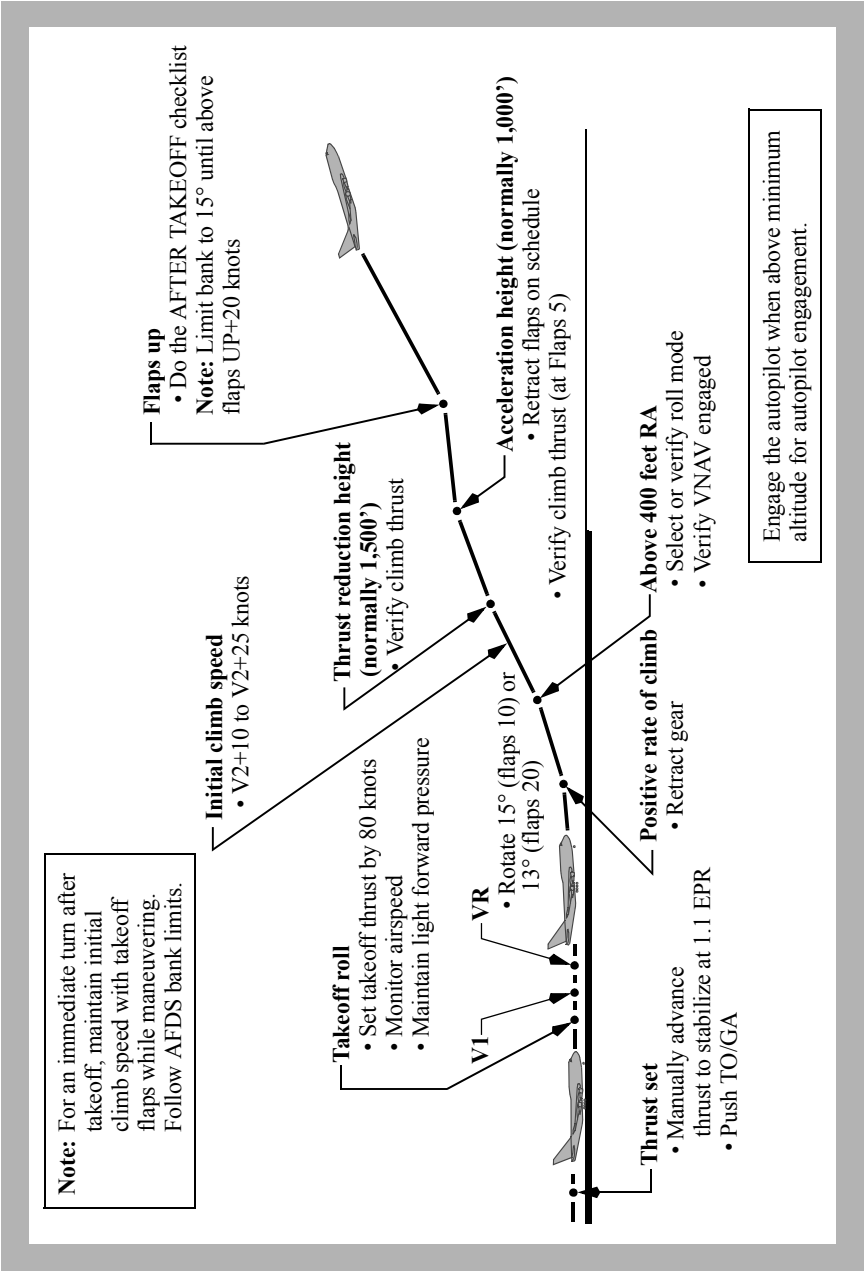
Takeoff Flap Retraction Speed Schedule

Takeoff Flaps	At Speedtape "Display"	Select Flaps
20	"10"	10
	"5"	5
	"1"	1
	"UP"	UP
10	"5"	5
	"1"	1
	"UP"	UP
Above 680,000 lbs, limit bank angle to 15° with flaps up until reaching UP + 20 knots.		

For flaps up maneuvering, maintain at least:

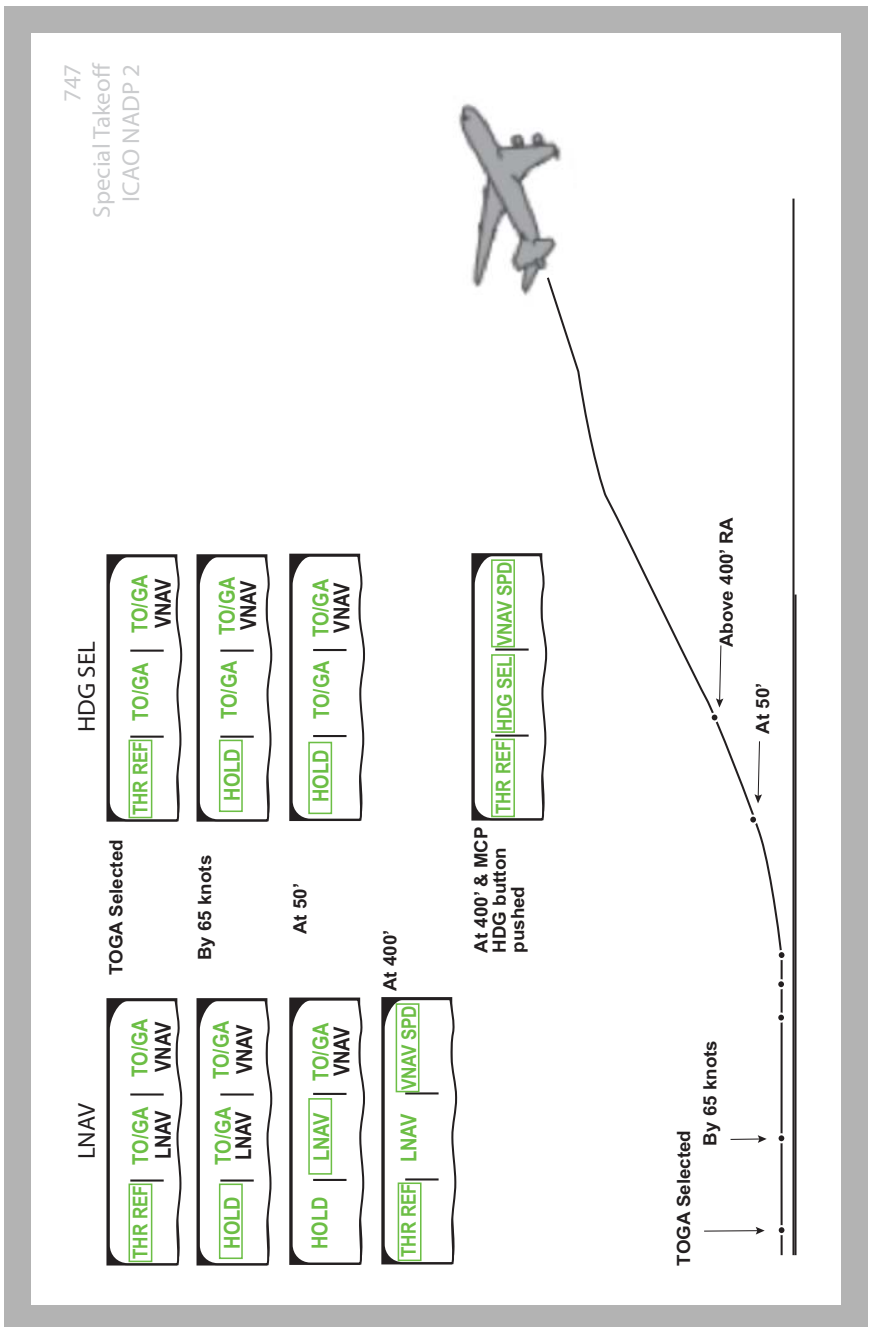
- "UP" or "UP + 20 knots" above 680,000 pounds

Normal Takeoff Profile (Distant/ICAO NADP 2)



DELTA
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FMA Progression



**Normal Takeoff (Distant/ICAO NADP 2)**

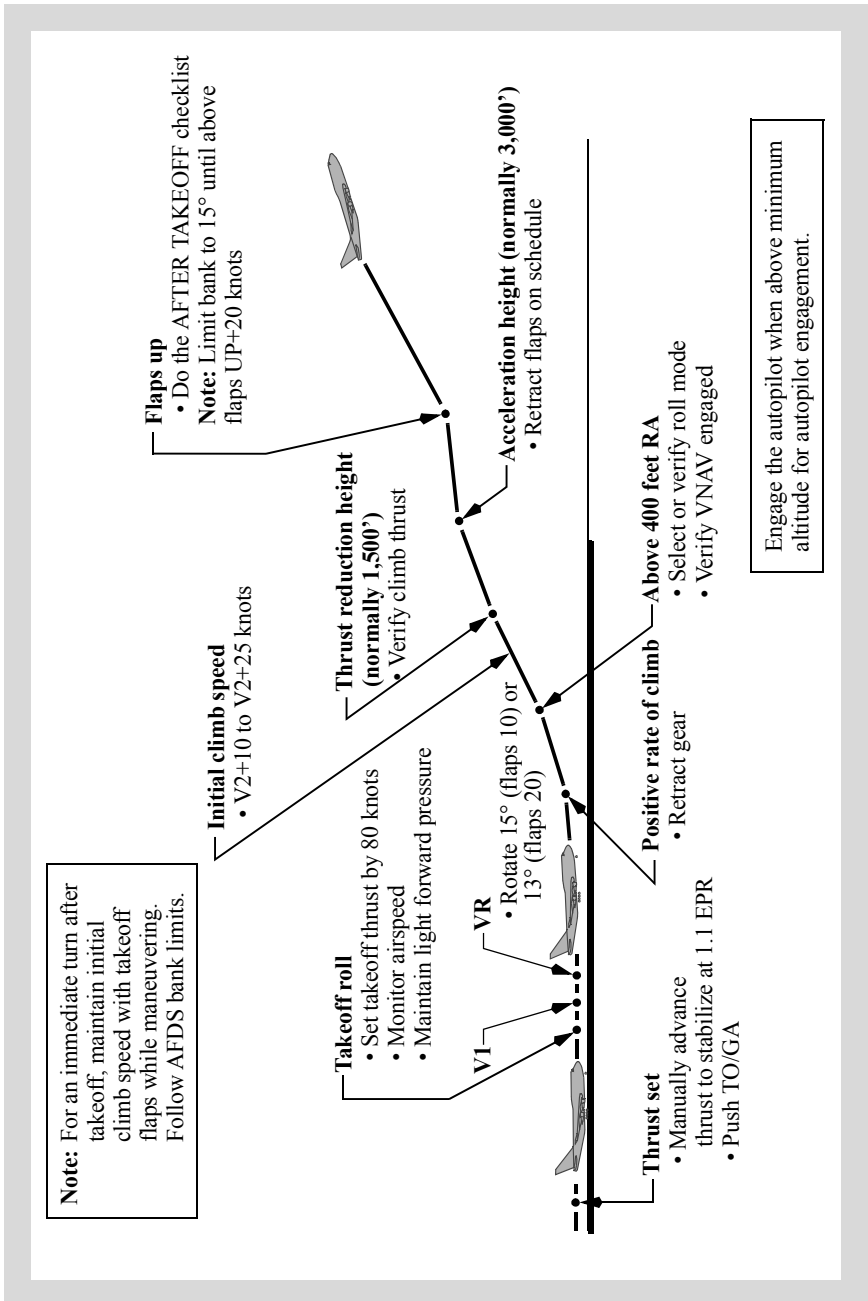
The Normal Takeoff profile (Distant/ICAO NADP 2) is the normal takeoff procedure and is the default FMS profile. The Distant/ICAO NADP 2 reduces noise slightly for communities that are not within the immediate vicinity of the runway end.

- 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.

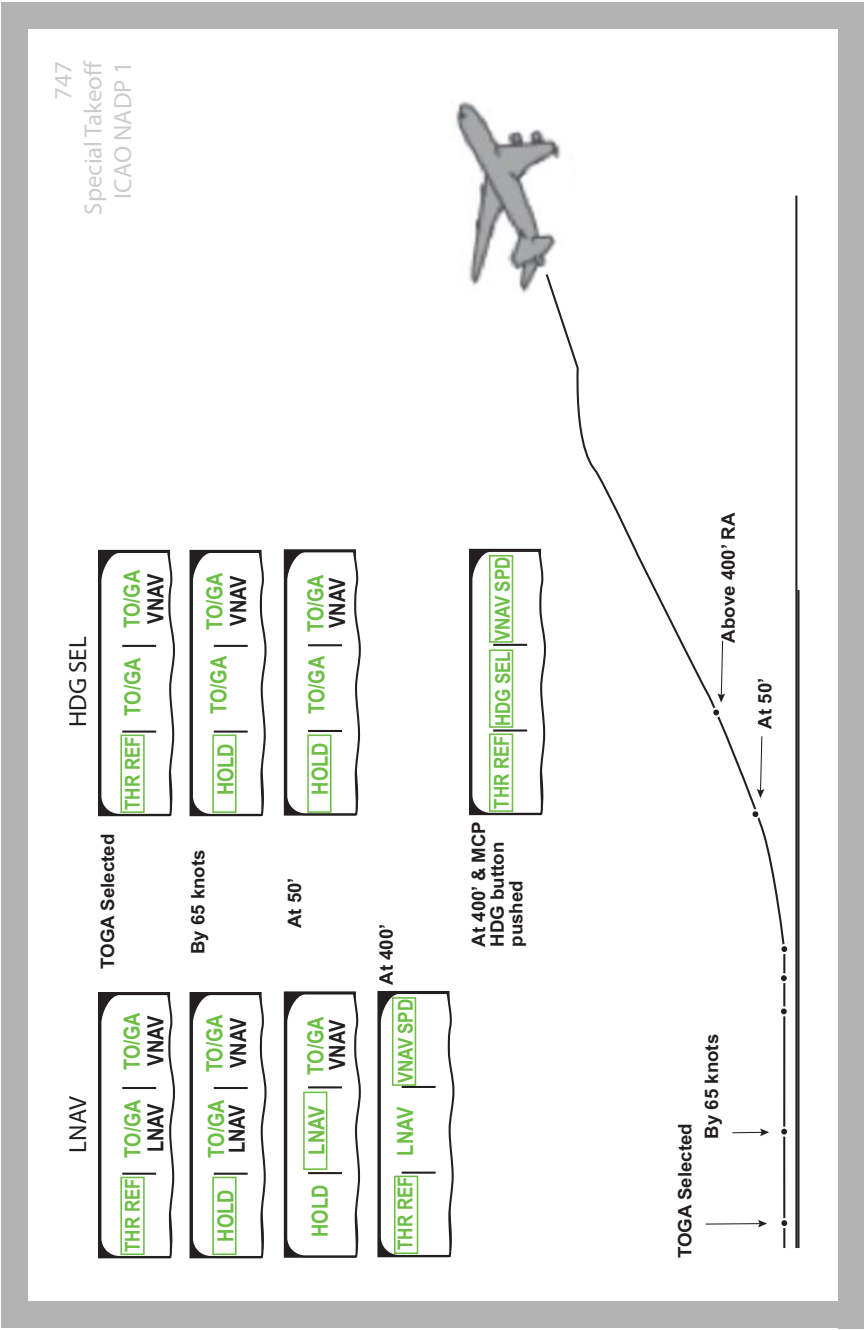
Note: AFDS will command appropriate pitch for acceleration segment.



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



FMA Progression



**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.

The Close-In/ICAO NADP 1 is not the default FMS profile and must be entered on Takeoff Page 2.

- 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 speed intervention or FLCH.

Note: Specific local airport procedures should be followed.

RNAV Departures

Preflight

Accomplish a full inertial/navigation system alignment prior to taxi (refer to steps in NP.20, Preflight Procedure - Pilot Flying).

Ensure the waypoints, speed, and altitude constraints of the RNAV SID selected from the database match those depicted on the published Jeppesen procedure for the departure runway.

Ensure that critical DMEs (if identified in any RNAV procedure) are operative.

Note: Critical DMEs do not apply to aircraft with GPS operative. All other aircraft depend on DME radio updating for navigation accuracy during RNAV DPs. Therefore, when operating ships with GPS inoperative, check the NOTAMS section of the flight plan to ensure that all critical DMEs are operative.

For ships with GPS inoperative and the TO/GA switch inoperative, immediately prior to pushback, consider a fast realignment of the IRSs to refine aircraft NAV position.

PDC

PDCs will state either CLIMB VIA or CLIMB MAINTAIN. Pilots must be diligent when reviewing PDCs.

**** PREDEPARTURE CLEARANCE ****

VERIFY PDC VALID TIME W/ATC IF MORE
THAN 90 MINUTES PAST SKED DEP TIME
DL440 DEPARTING PDX TRANSPONDER 5146
SKED DEP TIME HHHH EQUIP B747/H
FILED FLT LEVEL 250
ROUTING

-CLEARED AS FILED-
KPDX LAVAA# YKM CHINS# KSEA

LAVAA# DEPARTURE YKM TRANSITION CLIMB VIA SID
EXPECT REQ ALT 10 MIN AFTER DEPARTURE
CTC DEP 124.35



Before Takeoff

Ensure the departure runway selected in the FMS is consistent with the assigned departure runway and the associated first fix on the ND matches the assigned RNAV DP/ATC departure clearance.

When approaching the departure runway check aircraft versus runway position on the ND (10 NM scale).

On takeoff, FMC will not update position to the runway landing threshold for aircraft dispatched with the autothrottle or TO/GA switch inoperative. Verify the aircraft symbol is in close proximity to the departure end of the runway symbol with the ND in the 10 NM scale. Do not use LNAV for departure if FMS position is incorrect.

Note: For lateral alignment, when on the runway, the nose-tip of the aircraft triangle should be between, or very close to, the runway symbol edge lines. In 10 NM scale of the ND map display, the width of the runway symbol is 1,515 feet. Check position is also within 1,000 feet longitudinally.

CAUTION: If aircraft map position is greater than 1,000 feet from the actual runway takeoff position, or cannot be determined, for an RNAV departure request radar vectors to the first fix.

FMS will begin to search for suitable radio updates after the aircraft reaches 100 knots on takeoff roll.

Takeoff

The appropriate roll mode should be selected to comply with the departure procedure and clearance. If the departure procedure and clearance requires an LNAV track from the runway, arm LNAV before takeoff.

Pay close attention to takeoff clearance. "Delta 123, cleared for takeoff" is the standard clearance issued to fly the RNAV SID as published.

Use of the autopilot is strongly encouraged. Optimum course adherence is ensured if the autopilot is engaged at approximately 1,000 feet AFE. It is recommended to engage the autopilot after VNAV is selected and climb power is set.

Whenever a significant course change is depicted, expect the FMC to issue turn anticipation for fly-by waypoints (waypoints depicted on Jeppesen charts without a circle around them).



RNAV SID/STAR design is based on path keeping accuracy bounded within 0.5NM. Deviations are not acceptable. On the ND map display, the tip of the airplane symbol represents the precise present position of the aircraft. On straight-line flight path segments, the base of the airplane symbol approximates one-tenth of the selected ND map scale (e.g., in the 10 NM scale, the base of the airplane symbol represents approximately 1 NM). Pilots may use the airplane symbol or the appropriate progress page in the FMS to monitor path-keeping accuracy. Use PROG page 2/3 to monitor XTK error. During turns, commands from the flight director may direct an overshoot. Overlay the trend vector on the magenta line (or use an autopilot) to accurately fly the depicted route.

Notify ATC of any inability of the FMS to provide accurate navigation and request amended clearance.

Note: For normal operations, cross-track error/deviation (the difference between the displayed path and the displayed aircraft position relative to the displayed path) should be limited to half the navigation accuracy associated with the procedure (e.g., 0.5 NM for RNP 1). Brief deviations from this standard (e.g., overshoots or undershoots) during and immediately after turns, and up to a maximum of one times the navigation accuracy (e.g., 1.0 NM for RNP 1), are allowable.

Procedures

Pilots shall respond to “climb via” clearances by repeating the clearance verbatim. Phrases such as “on the” or “climbing on” a procedure are not acceptable and can create a miscommunication and additional workload with unnecessary controller queries. When changing frequencies or on initial contact, advise ATC of current altitude, “climbing via” procedure name. If an assigned altitude or speed is not contained on the SID, advise ATC of restrictions assigned by the prior controller.

Example of “climb via” check in:

- “Delta one twenty three, leaving niner thousand, climbing via the TRALR 5.”

If vectored off of an RNAV departure, ATC must provide a new altitude and heading. All restrictions are canceled, including any speed assignments, unless ATC provides another speed assignment.



Speed

Charted speed restrictions:

- When cleared for any arrival or departure procedure, charted speed restrictions must be complied with unless superseded by ATC.
- When there are charted speed restrictions, ATC can no longer use the phrase, “resume normal speed” to cancel speed restrictions. They must use the phrase, “delete speed restrictions”.
- To reassign charted speed restrictions, ATC must use the phrase, “resume published speed” or climb/descend via the procedure.
- When vectored off the procedure, ATC must issue a new altitude, and speed restrictions are canceled. When cleared back onto a procedure, any succeeding charted speed restrictions apply.

No charted speed restrictions:

- ATC may assign speed restrictions as necessary.
- To cancel speed restrictions, ATC may use either “resume normal speed” or “delete speed restrictions”.

Climb Via Phraseology and Speed Clearances

“Climb via” is an abbreviated clearance that requires compliance with the procedure lateral path, associated speed restrictions, and altitude restrictions along the cleared route or procedure.

Example:

- “Delta one twenty three, climb via the TRALR 5 departure.”

Following this clearance, comply with all altitude and speed restrictions, up to the top altitude published on the SID.

Note: The top altitude on the SID may vary based on runway assigned for takeoff.

Exception: If ATC revises the altitude clearance, they will state the new altitude using the phraseology “except”.

Example:

- “Delta one twenty three, climb via the TRALR 5 departure, except maintain FL230.”

This clearance requires compliance with all restrictions up to FL230, and any top altitude restriction is canceled



If vectored off of a SID, ATC must provide a new altitude and heading with the clearance. All SID restrictions are canceled, including any speed assignments (unless ATC provides another speed assignment.)

Example:

- “Delta one twenty three, turn right heading one three zero, maintain one two thousand.”

If cleared back to waypoint on the SID via a “climb via” clearance, and if there are any restrictions at that waypoint, the associated restrictions (altitude and speed) must be met.

Example:

- “Delta one twenty three, cleared direct WILLW, then climb via TRALR 5.”

“Climb and Maintain” Phraseology and Requirements

“Climb and maintain” requires vacating current altitude immediately and climbing to the “climb and maintain” altitude with no restrictions. If already climbing via a SID, all altitude restrictions are canceled unless re-issued by ATC.



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US Climb Via/Speed Adjustment Instructions and Requirements

ATC Instructions - FAA	FAA Requirements
CLIMB VIA	An abbreviated ATC clearance that requires compliance with the procedure lateral path, associated speed restrictions, and altitude restrictions along the cleared route or procedure. Subsequent issuance of a “maintain” clearance deletes published altitude restrictions.
CLIMB AND MAINTAIN (altitude)	Pilot is expected to vacate current altitude and commence an unrestricted climb to comply with the clearance. For aircraft already climbing via a SID, published altitude restrictions are deleted unless reissued by ATC.
COMPLY WITH RESTRICTIONS	Requires aircraft joining or resuming a procedure to comply with published restrictions. May be used in lieu of reissuing individual restrictions.
RESUME PUBLISHED SPEED	Cancels ATC assigned speed restrictions. Pilot is expected to comply with speeds published on the SID.
RESUME NORMAL SPEED	Cancels ATC assigned speed restrictions and instructs pilots to return to normal aircraft speed where no speed restrictions are published.
DELETE SPEED RESTRICTIONS	Cancels ATC assigned or published speed restrictions.



Takeoff - Engine Failure

General

Differences between normal and engine out profiles are few. One engine out controllability is excellent during takeoff roll and after liftoff. Minimum control speed in the air is below VR and VREF.

Engine Failure Recognition

Prior to V1

An engine failure at slow speeds prior to V1 quickly affects aircraft heading. Asymmetric thrust as a result of engine failure at low speeds (below VMCG) may result in a loss of directional control because of a lack of rudder effectiveness. The first indication of an engine failure is the induced yaw resulting from the asymmetrical thrust of the operating engines. Failure to promptly reduce thrust on the operating engines may result in a runway excursion. VMCG is defined as the minimum control speed on the ground, with the critical engine inoperative, takeoff power on other engines, using rudder control only for directional control.

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. Flying with lateral control wheel displacement or with excessive aileron trim causes spoilers to be raised.



Rotation and Liftoff - One Engine Inoperative

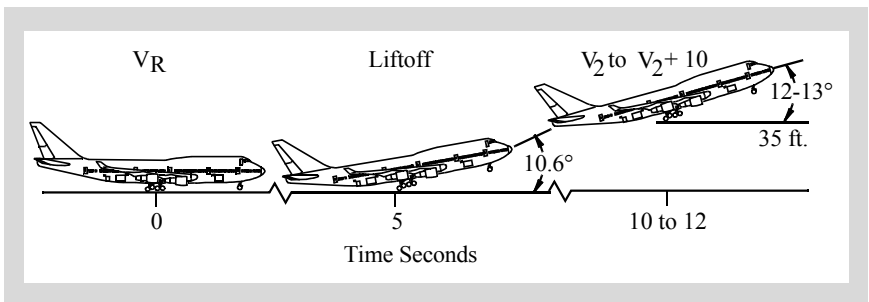
If an engine fails between V1 and liftoff, maintain directional control by smoothly applying rudder proportionate with thrust decay.

During a normal all-engine takeoff, a smooth continuous rotation toward 15° of pitch is initiated at VR. With an engine inoperative, a smooth continuous rotation is also initiated at VR; however, the target pitch attitude is approximately 2° to 3° below the normal all engine pitch attitude. 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.

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.

Typical Rotation - One Engine Inoperative

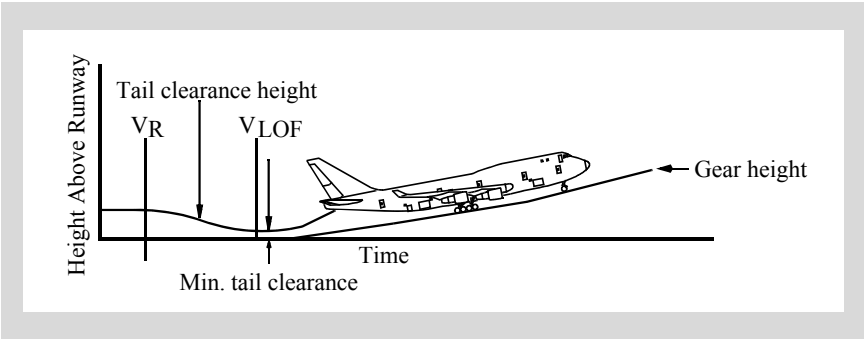
Liftoff attitude depicted in the following tables should be achieved in approximately 5 seconds. Adjust pitch attitude, as needed, to maintain desired airspeed of V2 to V2 + 10 knots.



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

Typical Takeoff Tail Clearance - One Engine Inoperative

The following diagram and table show the effect of flap position on liftoff pitch attitude and minimum tail clearance during takeoff with one engine inoperative. Additionally, the last column shows the pitch attitude for tail contact with wheels on the runway and landing gear struts extended. The tail strike pitch attitude remains the same as during takeoffs with all engines operating.



Model	Flaps	Liftoff Attitude (degrees)	Minimum Tail Clearance inches (cm)	Tail Strike Pitch Attitude (degrees)
747-400	10, 20	10.6	34 (86)	12.5

Initial Climb - One Engine Inoperative

The initial climb attitude should be adjusted to maintain a minimum of V2 and a positive climb. After liftoff the flight director provides 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 ground track after liftoff until another roll mode is selected. If ground track is not consistent with desired flight path, use HDG SEL/LNAV to achieve the desired track.

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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) has been attained. Due to asymmetric thrust considerations, it is recommended that the PF retard the affected thrust lever after the PM confirms that the PF has identified the correct engine. Accomplish the non-normal checklist items after the flaps have been retracted and conditions permit.

If an engine failure has occurred during initial climb, accomplish the appropriate checklist after the flaps have been retracted and conditions permit.

Initial Climb - Failure of a Second Engine

Should a second engine failure occur, increase thrust while maintaining directional control. If flaps are extended, retract them on schedule. If both failed engines are on the same side, a slight decrease in outboard engine thrust may be required to maintain directional control at low speeds. Return to maximum thrust as soon as rudder effectiveness permits.

During acceleration with two engines inoperative on one side, with flaps retracted and airspeed above aileron lockout speed (approximately 240 knots), the autopilot may not have sufficient aileron authority to maintain desired bank. If this occurs, the aircraft must be manually flown.

Immediate Turn after Takeoff - One Engine Inoperative

Obstacle clearance or departure procedures may require a special engine-out departure procedure. Refer to the 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). Maintain V_2 to $V_2 + 10$ with takeoff flaps while maneuvering.

Note: The AFDS limits the bank angle to 15° until $V_2 + 10$ knots to maintain at least adequate maneuver margin when LNAV is engaged (or HDG SEL is engaged and the bank limit is in AUTO). Bank angles up to 25° are permitted at $V_2 + 10$ knots with takeoff flaps.

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

Autopilot Engagement - One Engine Inoperative

When at a safe altitude above 250 feet AFE with correct rudder pedal or trim input, the autopilot may be engaged.



Flap Retraction - One Engine Inoperative

Acceleration height for a takeoff with an engine failure after V1 is based on accelerating to VREF + 100 knots while retracting flaps and selecting the maximum continuous thrust limits within 5 minutes (10 minutes optional) after initiating takeoff.

The standard altitude to initiate acceleration and flap retraction with an engine inoperative is 1,000 feet AFE. However, some combinations of high gross weight, takeoff flap selection, and airport elevation may require initiating flap retraction as low as 400 feet after takeoff with an engine failure.

At engine out acceleration height, if VNAV is engaged, a near-level climb segment is commanded for acceleration. Retract flaps on the takeoff flap retraction speed schedule. Airspeed commands to VREF + 100 knots. With flaps up and airspeed greater than VREF + 98 knots, VNAV automatically sets the reference thrust limit to Max Continuous Thrust (CON).

At engine out acceleration height, if VNAV is not engaged, select FLCH and flaps up maneuvering speed + 20 knots on the MCP. Engine-out acceleration and climb capability for flap retraction are functions of aircraft thrust-to-weight ratio. The flight director commands a near level flap retraction segment. Accelerate and retract flaps on the takeoff flap retraction speed schedule.

If the flight director is not being used at acceleration height, decrease pitch attitude to maintain approximately level flight while accelerating. Retract flaps on the takeoff flap retraction speed schedule.

As the aircraft accelerates and flaps are retracted, adjust the rudder pedal position to maintain the control wheel centered and trim to relieve rudder pedal pressure.

If the decision is made to remain in the pattern for a return to the departure airport, consider using flaps 5 for maneuvering to land. The following steps are recommended for acceleration at 1,000 feet AFE:

- Select the flaps 5 speed on the MCP.
- retract to flaps 5 on schedule.
- Upon reaching the flaps 5 speed, select the MCP THR button and check for Maximum Continuous Thrust (CON).
- Initiate the appropriate NNC and normal checklists as necessary.



Flaps Up - One Engine Inoperative

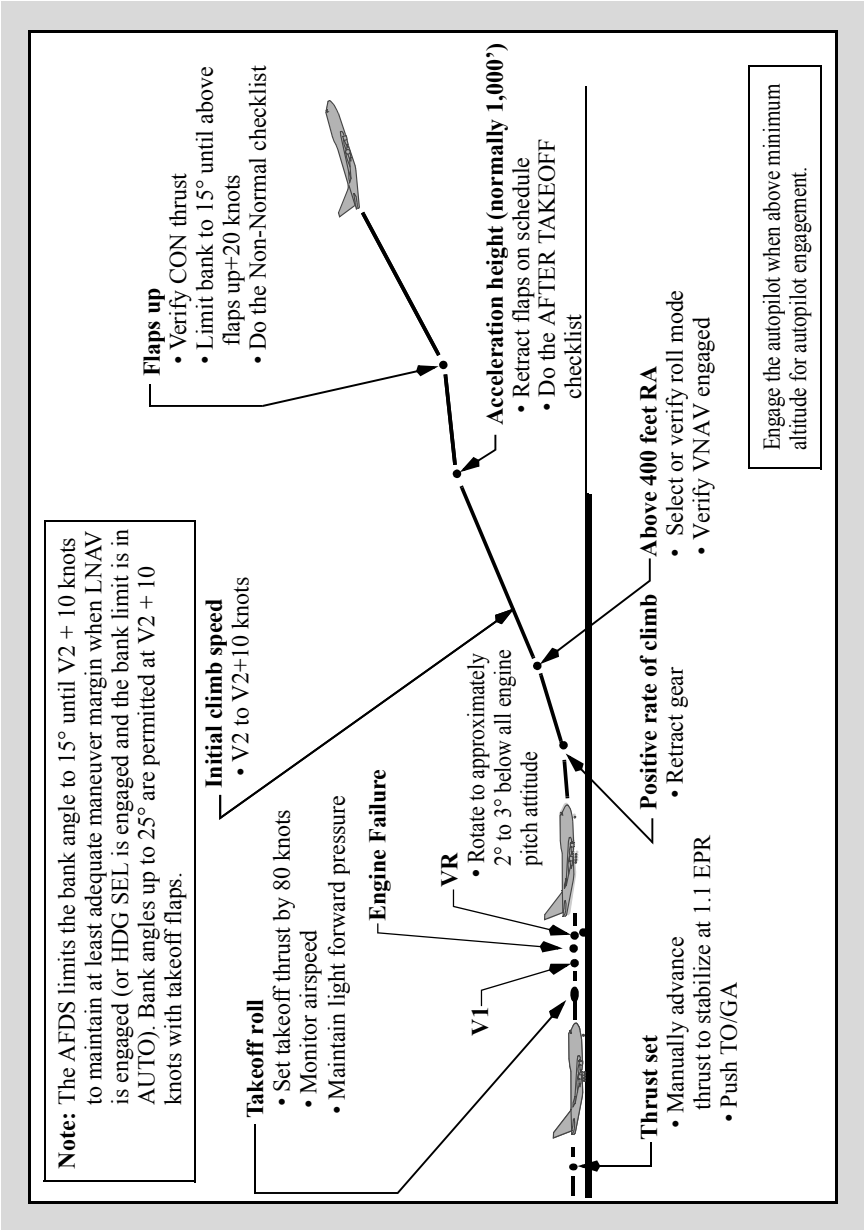
After flap retraction and at flaps up maneuvering speed +20 knots, if VNAV is not engaged, select THR, verify Maximum Continuous Thrust (CON) is set and continue the climb to the obstacle clearance altitude.

With flaps up, the FMS commands a climb at flaps up maneuvering speed + 20 knots and the autothrottles transition automatically to maximum continuous thrust if VNAV is engaged. If this does not occur, select FLCH and flaps up maneuvering speed until clear of obstacles. Maximum Continuous Thrust is set when THR is selected.

Note: When an engine failure occurs after takeoff, noise abatement is no longer a requirement.



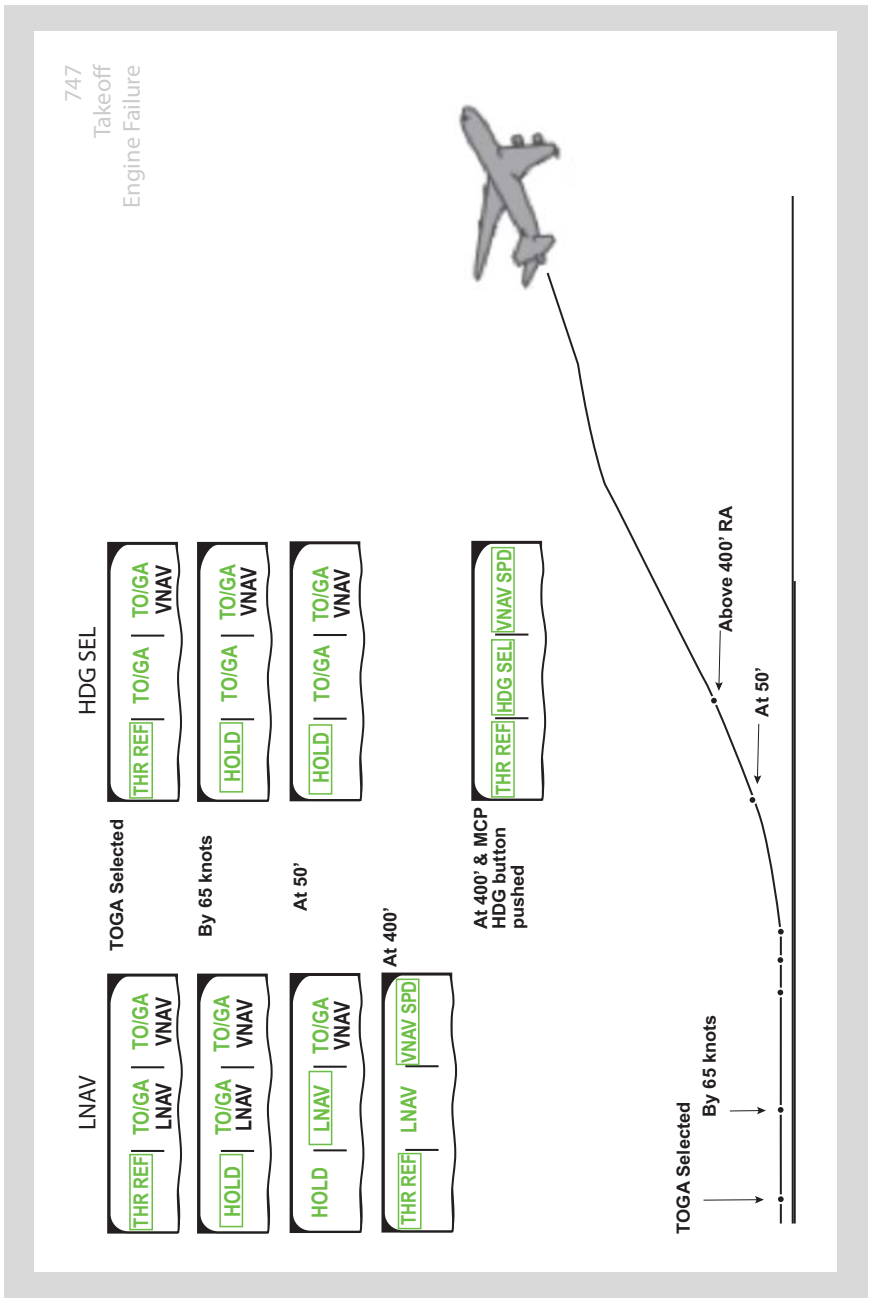
Takeoff Profile - Engine Failure





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Takeoff Profile - Engine Failure; FMA Progression





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 engines in the event of an engine failure. However, if more thrust is needed during an ATM takeoff, thrust on the operating engines may be increased to full rated takeoff thrust by manually advancing the thrust levers while still on the runway, or by pushing the TO/GA switch when airborne. This is because the takeoff speeds consider VMCG and VMCA at the full rated takeoff thrust.

Increasing thrust on the operating engines 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.

Engine Failure During a Derated Thrust (Fixed Derate) Takeoff

During a fixed derate takeoff, the takeoff speeds at low gross weights may not provide a safe operating margin to minimum control if the thrust levers are advanced. A thrust increase following an engine failure could result in loss of directional control and should not be accomplished unless, in the opinion of the captain, terrain contact is imminent. This is because the takeoff speeds consider VMCG and VMCA only at the fixed derate level of thrust.

Engine Failure During a Combined ATM and Fixed Derate Takeoff

During a takeoff using both ATM and fixed derate, any thrust increase beyond the fixed derate limit following an engine failure could result in loss of directional control. This is because the takeoff speeds consider VMCG and VMCA only at the fixed derate level of thrust. Since the crew has no indication of the fixed derate limit, a thrust increase should not be accomplished unless, in the opinion of the captain, terrain contact is imminent.

Climb, Cruise, Descent and Holding
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Climb

Reduced Thrust Climb

Engine service life may be extended by operating the engines at less than full climb rated thrust.

The FMS provides two reduced thrust climb selections on the THRUST LIMIT page:

- CLB 1 is a constant 10% derate of climb thrust.
- CLB 2 is a constant 20% derate of climb thrust.

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.

Climb thrust reductions are gradually removed as the aircraft climbs until full climb thrust is restored. If rate of climb should drop below approximately 500 feet per minute, the next higher climb rating should be selected.

Prior to takeoff, the pilot may override the automatically selected climb thrust limit after the takeoff selection has been completed by selecting another climb thrust limit on the THRUST LIMIT page. When the automatically selected climb thrust limit is overridden, the previously selected takeoff derate is not affected.

Climb Modes

There are three climb modes available: VNAV, Flight Level Change, and Vertical Speed.

VNAV

In VNAV SPD, flight director pitch guidance commands the pitch attitude to maintain speed. While in VNAV SPD, speed changes are accomplished by entering a new speed on the CLB page or speed intervention. Thrust is fixed as indicated by THR REF on the FMA.

In VNAV PATH, flight director pitch guidance commands the pitch to remain within departure or waypoint constraints.

FLCH

FLCH commands pitch guidance to maintain the speed in the MCP IAS/MACH window. The pitch mode annunciates FLCH SPD on the FMA. Thrust is fixed as indicated by THR REF on the FMA.

Shorter climbs occur at a reduced thrust setting.

V/S

Vertical Speed commands pitch guidance to maintain the vertical speed. The pitch mode will indicate V/S on the FMA. Thrust is varied to maintain the speed in the IAS/Mach window as indicated by SPD on the FMA.

Climb Constraints

Climb constraints may be automatically entered in the route when selecting a procedure, or manually entered through MCDU entry. All intermediate constraints must be displayed in LARGE FONT on the LEGS page.

When operating in VNAV always set the ATC clearance altitude in the MCP window.

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 FLCH or VNAV with MCP altitude intervention is recommended. Altitude intervention is accomplished by selecting the next desired altitude in the MCP altitude window, pushing the MCP altitude selector which deletes the altitude constraint and allows the aircraft to climb to the next altitude constraint or the MCP altitude, whichever is lower. Selecting CLB DIR will remove all altitude constraints between the aircraft altitude and the MCP altitude or FMC cruise altitude, whichever is lower. Waypoint constraints can also be manually deleted from the LEGS page.

Low Altitude Level Off

Occasionally a low altitude climb restriction is required after takeoff. This altitude restriction should be set in the MCP altitude window. When the aircraft approaches this altitude, the mode annunciation changes to ALT or VNAV ALT and the aircraft levels off. The autothrottle SPD mode engages and controls to the target speed. If altitude capture occurs while still in the TO/GA pitch mode, select the SPD autothrottle mode and set the desired command speed at level off.

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 AFDS 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.

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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,
- reduce from takeoff to climb thrust earlier than normal,
- 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 + 20 knots 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) or flaps maneuver speed +20 knots, 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.

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 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 windshield 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 or flaps up maneuvering speed + 20, whichever is greater, 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 /VREF 30 +100 knots, whichever is higher
- Above 10,000 feet - 340/0.84M

Maximum Rate Climb

A maximum rate climb provides both high climb rates and minimum time to cruise altitude. Maximum rate climb can be approximated by:

- flaps up Maneuver Speed + 60 knots until intercepting 0.82M

Note: The FMS does not provide maximum rate climb speeds.

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 + 20 knots.

Note: The FMS provides maximum angle climb speeds.



Engine Inoperative Climb

The recommended engine inoperative climb speed approximates the speed for maximum climb gradient and varies with gross weight and altitude. At high altitudes and weights, a fixed Mach is used as an upper limit on the engine-out climb speed. After flap retraction and all obstructions are cleared, on the FMS ACT ECON 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 engines and adjust the pitch to maintain airspeed.

The ENG OUT CLB page displays the maximum altitude and the engine out climb speed to cruise altitude, or maximum engine-out altitude, whichever is lower.

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

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

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 hourly 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
- Provides minimum cost operation for the selected cost index
 - 747-400 is optimized for flight between M.84 and M.86 at optimum altitude
 - 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 airspeed 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 or CAS values on the CRZ page target speed line. A manually entered Mach or indicated airspeed on the CRZ page is not automatically propagated to the DES page.

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

Required Time of Arrival (RTA) speed is generated to meet a time required at an RTA specified waypoint on the FMS RTA Progress Page 3.

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 9999 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.

Note: Thrust limits or maximum speed limits are generally encountered with cost index entries of 5,000 or more.

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.

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
- thrust limited altitude - the altitude at which sufficient thrust is available to provide a specific minimum rate of climb. Refer to the Maximum Recommended Initial Cruise 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. This altitude provides a g margin prior to buffet chosen by airline policy. The minimum margin available is 0.2g (33° bank) prior to buffet.

Although each of these limits are checked by the FMS, available thrust may limit the ability to accomplish anything other than relatively minor maneuvering. The amber band limits do not provide an indication of maneuver capability as limited by available thrust.

The minimum maneuver speed indication on the airspeed display does not guarantee the ability to maintain level flight at that speed. Decelerating the aircraft to the amber band 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 aircraft weight, cruise CG, and temperature entries are correct.

When operating at or near maximum altitude it is possible for LNAV inputs to exceed the capability of the aircraft. This could result in a loss of altitude or airspeed. Fly at least 10 knots above the lower amber band and consider using bank angles of 10° or less. If speed drops below the lower amber band, 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 lower amber band, any maneuvering increases the load factor and further reduces the margin to buffet onset and stick shaker.



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

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.

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 approximately a 1.3g load factor (approximately 40° bank prior to buffet onset) or better buffet margin. As deviation from optimum cruise altitude increases, still air performance economy deteriorates.

Some loss of thrust limited maneuver margin can be expected above optimum altitude. Levels 2,000 feet above optimum altitude normally allows approximately 40° bank prior to buffet onset. The higher the aircraft flies above optimum altitude, the more the thrust margin is reduced. Before accepting an altitude above optimum, determine that it will continue to be acceptable as the flight progresses under projected conditions of temperature and turbulence.

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.

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.

When requesting oceanic altitudes from clearance delivery, base them on the FMS Optimum altitude rather than the filed flight plan altitude.

Step Climb

Flight plans not constrained by short trip distance are typically based on conducting the cruise portion of the flight close to optimum altitude. Since the optimum altitude increases as fuel is consumed during the flight, it is necessary to climb to a higher cruise altitude periodically to achieve the flight plan fuel burn. This technique, referred to as Step Climb Cruise, is typically accomplished by entering an appropriate step climb value in the FMS according to the available cruise levels. For most flights, one or more step climbs may be required before reaching TOD.

It may be especially advantageous to request an initial cruise altitude above optimum if altitude changes are difficult to obtain on specific routes. This minimizes the possibility of being held at a low altitude/high fuel consumption condition for long periods of time. The requested/accepted initial cruise altitude should be compared to the thrust limited or the maneuver margin limited altitudes. Remember, a cruise thrust limited altitude is dependent upon the cruise level temperature. If the cruise level temperature increases above the chart value for gross weight, maximum cruise thrust will not maintain desired cruise speed.

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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.

Note: FMS default values for the step climb may not be appropriate for RVSM or metric airspace. Manually enter the appropriate step climb values as needed.

Fuel for Enroute Climb

The additional fuel required for a 4,000 foot enroute climb varies from 500 to 650 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.

FMS Wind Entries

Wind and temperature 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 and temperature FMS entries during the preflight, enter as many wind and temperature values as feasible. The remaining entries can be completed as workload permits.

Entering the wind and temperature values for all available flight levels and waypoints will ensure the most accurate FMS predictions. The range of flight levels must be entered for all waypoints. For example, if the wind and temperature values for FL 290 are entered at the initial waypoint, then they must be entered at that altitude for all subsequent waypoints.

Wind and temperature values propagate along the route; therefore, enter new wind values for subsequent waypoints only when a difference exceeding 10° or 10 knots exists from the previous waypoint. Enter a new temperature value for subsequent waypoints only when a difference of +/- 2° exists.

MCDU Recruising Procedures

(Changes in programmed cruise altitude other than what has been accepted).

Re-cruising Higher

- MCP Altitude knob is pushed one time after the new, higher altitude is set in the MCP Altitude Window. Pushing the MCP knob will automatically change the cruise altitude on the VNAV Climb page.

Re-cruising Lower

- During climb, the MCP Altitude knob function will not allow change to a lower cruise altitude until the initial cruise altitude is reached; therefore the new, lower cruise altitude must be manually entered on the VNAV Climb page (entered at 1L).
- If level at an intermediate altitude and told that it will be the final altitude, the MCP altitude knob “push” function will not allow change to lower cruise altitude; therefore the current altitude must be manually entered on the VNAV Climb page (entered at 1L).
- After manually entering the altitude, the MCP Altitude knob must be pushed one time (known as the “handshake”). VNAV will remain in VNAV ALT (not VNAV PATH) until the altitude is entered on the VNAV Climb page and the MCP Altitude knob is pushed.

Low Fuel Temperature

Fuel temperature changes relative to total air temperature. For example, extended operation at high cruise altitudes tends to reduce fuel temperature. In some cases the fuel temperature may approach the minimum fuel temperature limit.

Fuel freezing point should not be confused with fuel ice formation caused by frozen water particles. The fuel freezing point is the temperature at which the formation of wax crystals appears in the fuel. The Jet A fuel specification limits the freezing point to -40°C maximum, while the Jet A-1 limit is -47°C maximum. In the Commonwealth of Independent States (CIS), the fuel is TS-1 or RT, which has a maximum freezing point of -50°C, which can be lower in some geographical regions. The actual uplifted freezing point for jet fuels varies by the geographical region in which the fuel is refined.

Unless the operator measures the actual freezing point of the loaded fuel at the dispatch station, the maximum specification freezing point must be used. At most airports, the measured fuel freezing point can yield a lower freezing point than the specification maximum freezing point. The actual delivered freezing temperature can be used if it is known. Pilots should keep in mind that some airports store fuel above ground and, in extremely low temperature conditions, the fuel may already be close to the minimum allowable temperature before being loaded.

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For blends of fuels, use the most conservative freezing point of the fuel on board as the freezing point of the fuel mixture. This procedure should be used until three consecutive refuelings with a lower freezing point fuel have been completed. Then the lower freezing point may be used. If fuel freezing point is projected to be critical for the next flight segment, wing tank fuel should be transferred to the center wing tank before refueling. The freezing point of the fuel being loaded can then be used for that flight segment.

Fuel temperature should be maintained within AFM limitations as specified in the Limitations chapter of the Vol. 1.

Maintaining a minimum fuel temperature should not be a concern unless the fuel temperature approaches the minimum temperature limit. The rate of cooling of the fuel is approximately 3° C per hour, with a maximum of 12° C per hour possible under the most extreme conditions.

Total air temperature can be raised in the following three ways, used individually or in combination:

- climb or descend to a warmer air mass,
- deviate to a warmer air mass,
- increase Mach number.

Note: In most situations, warmer air can be reached by descending but there have been reports of warmer air at higher flight levels. Air temperature forecasts should be carefully evaluated when colder than normal temperatures are anticipated.

It takes from 15 minutes to one hour to stabilize the fuel temperature. In most cases, the required descent would be 3,000 to 5,000 feet below optimum altitude. In more severe cases, descent to altitudes of 25,000 feet to 30,000 feet might be required. An increase of 0.01 Mach results in an increase of 0.5° to 0.7° C total air temperature.

Delta Air Lines has developed a Fuel Freeze Program. Refer to Vol. 1, SP.12, Fuel Freeze Program.

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,
- cruise altitude more than 2,000 feet above optimum altitude,
- 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, and
- excessive thrust lever adjustments.

Cruise fuel penalties can be approximated using the following guidance:

- ISA + 10° C: 1% increase in trip fuel,
- 2,000 feet above optimum altitude: 1% to 2% increase in trip fuel,
- 4,000 feet below optimum altitude: 2% to 6% increase in trip fuel,
- 8,000 feet below optimum altitude: 6% to 14% increase in trip fuel,
- cruise speed 0.01M above LRC: 2% increase in trip fuel.

For cruise within 2,000 feet of optimum, long range cruise speed can be approximated by using 0.86M. 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

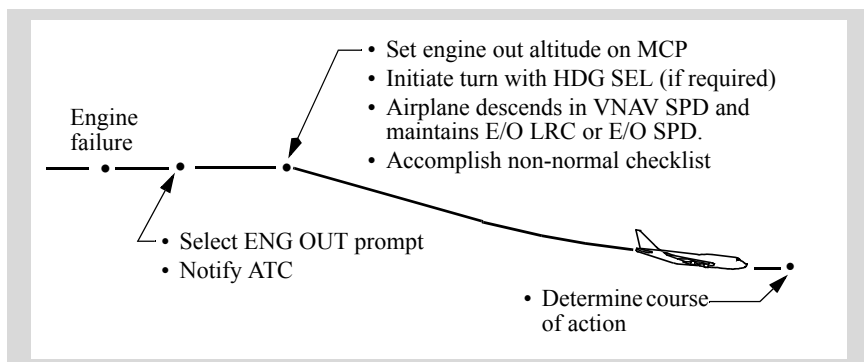
If an engine failure occurs during cruise apply rudder and trim to level the control wheel. This allows the autopilot to remain engaged. The autothrottle remains active with one engine inoperative.

- If a delay in descent is necessary (e.g. traffic, track offset or clearance), select the ENG OUT prompt on the VNAV CRZ page and execute without delay. The FMS commands E/O LRC and sets maximum CON thrust. Set the level-off altitude in the MCP. Decelerating below command speed (E/O LRC) prior to beginning descent may be required to allow additional time at the assigned altitude. At command speed, but no slower than flaps up maneuvering speed, push the MCP altitude selector to descend. If the airspeed has decreased below FMS command speed, the descent rate increases to regain the FMS command speed during descent. This method results in the most fuel efficient profile.
- If terrain is a factor, set the MCP altitude to the engine out maximum altitude. Select the E/O SPD prompt on the engine out page and execute to descend. The cruise altitude becomes engine-out maximum altitude, the FMS commands E/O SPD and the thrust reference is CON. This method results in the shallowest descent profile and level off at the highest possible engine-out altitude.

If a delay in descent is not required and terrain is not a factor, all engine LRC, all engine ECON, or company speed may be used for driftdown. After selecting the desired speed, set an altitude lower than the engine-out maximum altitude in the MCP and push the altitude selector. The airplane descends in a VNAV cruise descent at the selected speed.

If the airplane is in cruise below the engine-out maximum altitude, enter the current cruise altitude on the modified engine-out page and execute. The FMS command speed is engine out E/O LRC, and the reference thrust is CON.

If a second engine fails, the FMS computes and displays two engine out data automatically. The autothrottle does not remain active with two engines inoperative.



High Altitude Performance

The aircraft exhibits excellent stability throughout the high altitude / high Mach range. Mach buffet is not normally encountered at high Mach cruise. The aircraft does not have a Mach tuck tendency.

As speed nears MMO, drag increases rapidly. At high weights, sufficient thrust may not be available to accelerate to MMO in level flight at normal cruising altitudes.

Note: Wings level buffet Mach number is well above MMO.

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.

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

On occasion, aircraft have experienced low speed events at cruise altitude where a descent is necessary to regain cruise airspeed. Such cases often result from changing atmospheric conditions where the aircraft becomes thrust limited e.g., higher than standard temperatures aloft. Unexpected turbulence, mountain wave activity, altitude selection above recommended FMS altitudes, and exchanging airspeed for altitude for a rapid climb can also contribute to being slow at cruise altitude.

Prevention includes being aware of FMS-predicted maximum and recommended altitudes, planned and actual cruise airspeed, and known areas of turbulence or mountain wave activity. Crews should also be familiar with basic engine settings such as N1, EPR, and fuel flow.

Should the aircraft slow below acceptable airspeeds, be proactive in initiating the required descent to regain cruise airspeed.

Polar Operations

Refer to the Airway Manual, Pacific Theater, Polar for specifics about operating in polar regions and a description of the boundaries of the polar regions.

During preflight planning extremely cold air masses should be noted and cold fuel temperatures should be considered. See the Low Fuel Temperature section in this chapter for details regarding recommendations and crew actions.

Due to limited availability of alternate airports relative to other regions, special attention should be given to diversion planning including airport conditions and availability of compatible fuel. Crews should be prepared to operate in QFE and metric altitude where required. Expect changes in assigned cruising levels enroute since standard cruising levels vary by FIR. Some airports provide QNH upon request, even if their standard is QFE. Metric wind speed (m/sec) may be all that is available. A simple approximation: 1 m/sec = 2 knots. A feet to meters conversion chart may be useful for planning step climbs, converting minima, etc.

Use caution when using ADF and/or VOR raw data. ADF orientation (true or magnetic) is determined by the heading reference selected by the crew. VOR radials are displayed according to the orientation of the VOR station.

Communications should be handled according to the applicable enroute charts. Above 82 degrees N, SATCOM is unavailable. HF frequencies and HF SELCAL must be arranged by the flight crew prior to the end of SATCOM coverage. Routine company communications procedures should include flight following to enable immediate assistance during a diversion or other emergency.

Note: To use SATCOM on the ground, the IRUs must be aligned.



When navigating in the polar regions, magnetic heading should be considered unreliable or totally useless for navigation. Magnetic variations typically are extreme, often are not constant at the same point and change rapidly as airplane position changes. Ensure the computer flight plan shows true tracks and true headings. Grid headings may also be used as a reference for those airplanes equipped with grid heading indicators although no airplane systems use grid heading. For some high latitude airports, grid headings are shown on the instrument approach procedures. Note that unmapped areas in the GPWS terrain database display as magenta dots on the map, regardless of the airplane altitude.

The primary roll mode for polar operations should be LNAV, which may be used with the heading reference switch in the NORM position. HDG SEL/HOLD are functional but require the manual selection of TRUE heading reference. Deviations from planned route may be accomplished in HDG SEL.

If either the North Pole (NPOLE, N90EXXXXX or N90WXXXXX) or the South Pole (S90EXXXXX or S90WXXXXX) waypoint is used, a rapid heading and track reversal occurs passing the polar waypoint. If operating in HDG SEL/HOLD while near either pole, it is necessary to frequently update the heading selector to reflect the rapidly changing and/or reversed heading or the AFDS will command an unwanted turn. For this reason, LNAV is the preferred roll mode.

Loss of both GPS units or loss of GPS updating results in an increased ANP and possible display of the UNABLE RNP message, but normally does not prevent polar operation.

Loss of one or two IRUs does not significantly affect navigation accuracy. Operation on one remaining IRU should be limited to diversion to the nearest suitable airport.

ETOPS

ETOPS is not approved for the aircraft.



Descent

Descent Planning

Determine the arrival and approach to be flown. If no STAR is expected, ensure there is a waypoint and altitude constraint on the LEGS page that provides a valid T/D point for a descent to the terminal area, e.g. 250 kts at 10,000 ft 30 miles from the airport. If expecting a STAR or R/D (runway dependent) STAR, select the STAR, approach and appropriate transitions as specified in Vol. 1, SP.11. Verify the waypoints and any associated altitude and airspeed restrictions, including “Expect” constraints, match the ATC clearance and the charted Jeppesen procedure. 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.

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.

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.

STAR and RNAV STAR Descents

RNAV and conventional “descend via” STAR procedures aid arrival flows and reduce fuel burn, emissions, and pilot/controller communications. Pilots must understand this phraseology to avoid misinterpreting ATC instructions. Any time there is a question about a clearance, ask for clarification from the controller.



Descend Via

“Descend via” is an abbreviated ATC clearance that requires compliance with the procedure’s lateral and vertical paths, and associated speed and altitude restrictions, as published. The bottom altitude on a STAR or STAR runway transition is the lowest published or ATC assigned altitude authorized and is not to be mistaken for the minimum enroute altitude (MEA). ATC may issue a “descend via” clearance without a runway assignment, which authorizes pilots to navigate laterally and vertically to the end of the common route.

Note: If not cleared for a runway transition, the bottom altitude is the lowest altitude prior to the transition. This is the last common waypoint on the STAR.

Pilots shall respond to “descend via” clearances by repeating the clearance verbatim. Phrases such as “on the” or “descending on” a procedure are not acceptable and can create a miscommunication and additional workload with unnecessary controller queries. When changing frequencies, or on initial contact, advise ATC of current altitude, “descending via” procedure name, and runway transitions if assigned. If assigned an altitude or speed that is not contained on the STAR, advise ATC of restrictions assigned by the prior controller.

Examples of check in:

- “Delta one twenty-three, leaving FL190, descending via the RPTOR 3. Information Alpha.”

If vectored off of a STAR, ATC must provide a new altitude and heading. All restrictions are canceled, including any speed assignments unless ATC provides another speed assignment.



Speed

Charted speed restrictions:

- When cleared for any arrival or departure procedure, charted speed restrictions must be complied with unless superseded by ATC.
- When there are charted speed restrictions, ATC can no longer use the phrase, “resume normal speed” to cancel speed restrictions. They must use the phrase, “delete speed restrictions”.
- To reassign charted speed restrictions, ATC must use the phrase, “resume published speed” or climb/descend via the procedure.
- When vectored off the procedure, ATC must issue a new altitude, and speed restrictions are canceled. When cleared back onto a procedure, any succeeding charted speed restrictions apply.

No Charted Speed Restrictions:

- ATC may assign speed restrictions as necessary.
- To cancel speed restrictions, ATC may use either, “resume normal speed” or “delete speed restrictions”.



US Descend Via/Speed Adjustment Instructions and Requirements

ATC Instructions - FAA	FAA Requirements
DESCEND VIA	An abbreviated ATC clearance that requires compliance with a published procedure lateral path and associated speed restrictions, and provides a pilot-discretion descent to comply with published altitude restrictions.
DESCEND AND MAINTAIN (altitude)	Pilot is expected to vacate current altitude and commence an unrestricted descent to comply with the clearance. For aircraft already descending via a SID, published altitude restrictions are deleted unless reissued by ATC.
COMPLY WITH RESTRICTIONS	Requires aircraft joining or resuming a procedure to comply with published restrictions. May be used in lieu of reissuing individual restrictions.
RESUME PUBLISHED SPEED	Cancels ATC assigned speed restrictions. Pilot is expected to comply with speeds published on the STAR.
RESUME NORMAL SPEED	Cancels ATC assigned speed restrictions and instructs pilots to return to normal aircraft speed where no speed restrictions are published.
DELETE SPEED RESTRICTIONS	Cancels ATC assigned or published speed restrictions.

ICAO & US Phraseology Differences

PANS-OPS	US FAA
When an arriving aircraft on a STAR is cleared to descend to a level lower than the level or the level(s) specified in a STAR, the aircraft shall follow the published vertical profile of a STAR, unless such restrictions are explicitly canceled by ATC. Published minimum levels based on terrain clearance shall always be applied.	When ATC issues an amended altitude without specifying the point at which the restriction begins, ends, or changes the charted restrictions (e.g., using the word “except”), it thereby cancels altitude restrictions contained in the STAR but not any published speed restriction.



STAR/RNAV STAR Common Runway Transition Approach Clearance

Refer to chapter 5, Approach.

Calculation of 3:1 Descent Ratio

A 3:1 descent ratio can be used as a backup to an FMS generated idle descent path. A 3:1 descent rate approximates losing 1,000 feet every 3 miles.

The equation is: $(\text{altitude to lose}/1,000) \times 3 = \text{distance required}$.

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, $25 \times 3 = 75$. 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. $15 \times 3 = 45$ 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 engine anti-ice or if a speed reduction is expected.

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 (typically 10,000 feet or FL100), the airspeed is reduced to the airport speed restriction speed in the navigation database minus 10 knots (typically 240). 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. If desired, the ECON speed schedule can be modified by alternate Mach, Mach/IAS, or IAS values on the DES page target speed line. If the FMS information is not available, use target speeds from the Descent Rates table in this chapter.

Descent Path

An FMS idle path descent from cruise to the initial altitude/speed constraint is the most economical descent method. At least one waypoint-related altitude constraint below cruise altitude on a LEGS page generates a descent guidance path and a TOD. A path is created, assuming idle thrust or approach idle below the anti-ice altitude entered on the DESCENT FORECAST page, from the TOD to the highest large font altitude constraint on the LEGS page.

Subsequent constraints are vertical path segments (straight line point-to-point paths), which may be shallower than idle thrust paths. Therefore, there is a difference between an idle path from cruise and a geometric path between subsequent 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.

The main goal is fuel savings - providing maximum time at the highest altitude.

Descent Constraints

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

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



VNAV PTH pitch mode may require the use of speedbrakes or increased thrust to maintain the desired airspeed. Shallow vertical path segments may result in the autothrottle supplying partial thrust to maintain the target speed. On steeper vertical path segments, if the aircraft cannot maintain speed below the upper limits at idle power, it will depart the path if no action is taken and the pitch mode will change to VNAV SPD. Drag devices must be extended to stay on or recapture the path and achieve a speed reduction. 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.

Note: The DRAG REQUIRED message indicates the aircraft is unable to maintain the descent path and stay within speed tolerances unless speed brakes are extended.

Note: Application of speedbrakes while on the VNAV path will result in aircraft slowing while remaining on VNAV path and does not aid in increasing descent rate.

Speed Intervention

VNAV speed intervention can be used to respond to ATC speed change requirements. During speed intervention, VNAV SPD will replace VNAV PTH as the pitch mode. Speed becomes the priority and altitude constraints may not be assured. VNAV SPD pitch mode responds to speed intervention by changing aircraft pitch while the thrust remains at idle.

When the IAS/MACH selector is pushed during descent with the flaps UP, FMS speed-intervention becomes active and the IAS/MACH window opens. While the vertical path is still displayed on the ND, target speed becomes the descent priority and VNAV SPD is annunciated. The result is similar to FLCH, where thrust is reduced to idle and the aircraft varies pitch to maintain the target airspeed. Since VNAV SPD varies the pitch and resulting descent rate to maintain airspeed, the FMS makes no attempt to honor a descent path and may not meet altitude and/or airspeed restrictions displayed on the LEGS page, resulting in a violation. If on the idle path and ATC issues a speed reduction, program the FMS speed reduction and anticipate the need for speed brakes in order to maintain/return the aircraft to the new FMS-programmed idle path.

When the FMS has transitioned to approach mode, descent logic allows speed intervention to occur while remaining in VNAV PATH. FMS approach mode occurs:

- a VFR approach is created and,
 - the airplane has sequenced the FXXXX, or
 - the airplane is enroute to a direct-to or intercept-to the RWYYY waypoint and the airplane is within 25 nm of the runway threshold
- a published instrument approach has been selected and incorporated in the active flight plan and the airplane has sequenced the first waypoint on the published approach

In VNAV PATH while in the approach mode, the vertical path is flown at the target speed selected in the IAS/MACH window.

Offpath Descent

The LEGS pages should reflect the planned arrival procedure. If a published arrival procedure is required for reference while being radar vectored, or the arrival is momentarily interrupted by a heading vector from ATC, the offpath descent circles provide a good planning tool to determine drag and thrust requirements for the descent.

The outer circle is referenced to the end of descent point, using a clean configuration and a direct path from the aircraft position to the end of descent waypoint constraint. The inner circle is referenced to the end of descent point using speedbrakes. A separate waypoint may be entered on the OFFPATH DES page as a reference for the descent circles.

Both circles assume normal descent speed schedules, including deceleration at transition altitude, but do not include waypoint speed and altitude constraints.

The OFFPATH DES circles are referenced to the end of descent point displayed at 1L. The end-of-descent point from the descent page is displayed at 1L, however any valid waypoint from the NAV database can be entered at 1L. The OFFPATH DES page is displayed by pushing 6L on the descent page. In order to display the OFFPATH DES circles, select 6R. When the aircraft altitude is within 150 feet of the waypoint at 1L, the display defaults to the new end-of-descent point from the DESCENT page. The speed/altitude restriction for the waypoint at 1L is displayed in 1R. The ECON SPD or SEL SPD on the OFFPATH DES page needs to be accurate in order to provide valid information.

Early Descent from Cruise

The most fuel-efficient method to depart VNAV CRZ is to allow the aircraft to reach T/D and intercept the idle path. If required to descend early (prior to T/D), analyze whether a cruise descent or DES NOW is appropriate.

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In general terms, if outside 50nm of the TOD and required to descend, a cruise descent is an appropriate choice. While in VNAV, entering a lower cruise altitude in the MCP and pushing the altitude selector will result in the FMS commanding a 1,250 fpm descent until the new cruise altitude is reached. If the new idle descent path is intercepted prior to leveling at the new cruise altitude, the aircraft will capture the VNAV PTH descent profile. 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.

If it is determined that the idle path can be intercepted prior to leveling at the assigned altitude, then DES NOW is the better option. When DES NOW is executed, the aircraft enters the descent mode at 1,250 fpm. DES NOW commands the aircraft to depart the cruise mode and maintain 1,250 fpm until it reaches the MCP altitude or captures the VNAV PTH, whichever occurs first. After establishing the initial descent rate, the autothrottles will change to Hold and power can be increased to shallow the rate of descent to allow the idle path to be intercepted at a higher altitude.

Whenever the aircraft departs the CRZ mode using DES NOW, a vertical path deviation scale will immediately display on the HSI/ND. The below-path distance depends on how early the descent was initiated and can be displayed on the ND (if installed) and monitored on PROG Page 2/3.

Approaching Top-of-Descent (TOD)

If a lower altitude has not been selected in the MCP when within two minutes of the TOD point, a “RESET MCP ALTITUDE” message appears on the FMS scratchpad. If the TOD point is reached without a lower altitude set in the MCP, the pitch mode changes from VNAV PTH to VNAV ALT.

VNAV Descent From Above Path

When descending in VNAV SPD and well above the indicated VNAV PATH, an increase in descent rate may be required to acquire the VNAV PATH. An increase in speed and/or drag will increase the descent rate, which will aid in joining the VNAV PATH. Speed changes using the FMS DESCENT page will “redraw” the VNAV PATH based on the updated speed. If speed intervention is used to increase the speed, deselect speed intervention (close the MCP IAS/MACH speed window) as the VNAV PATH is regained.

Descent Rates

Descent Rate tables provide 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
0.83M / 340 knots	2800 fpm	4300 fpm
250 knots	1300 fpm	2100 fpm
VREF 30 + 100	1200 fpm	1900 fpm

Normally, descend with idle thrust and in clean configuration (no speedbrakes). Maintain cruise altitude until the TOD and then maintain 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 90 seconds and 8 nm to decelerate from 340 to 250 knots in level flight without speedbrakes. It requires an additional 13 seconds and 1 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 40%.

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



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.

To avoid buffeting, use of speedbrakes with flaps greater than 5 should be avoided. If circumstances dictate the use of speedbrakes with flaps extended, high sink rates during the approach should be avoided. Speedbrakes should be retracted before reaching 1,000 feet AGL.

The flaps are normally not used for increasing the descent rate. Normal descents are made in the clean configuration to pattern or instrument approach altitude.

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.

Extend the flaps when in the terminal area and conditions require a reduction in airspeed below flaps up maneuver speed. Normally select flaps 5 prior to the approach fix going outbound, or just before entering downwind on a visual approach.

Engine Icing During Descent

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

The use of 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 anti-ice use altitude should be entered on the DESCENT FORECAST page to assist the FMS in computing a more accurate descent profile.

Engine icing may form when not expected and may occur when there is no evidence of icing on the windshield 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 induce icing.

Note: The engine anti-icing system should be ON whenever icing conditions exist or are anticipated.

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 Airway Manual, Ops Specs, Maximum Holding Airspeeds.

If the FMS holding speed is greater than the ICAO or FAA maximum holding speed, holding may be conducted at flaps 1, using flaps 1 maneuver speed. Flaps 1 uses approximately 10% more fuel than flaps up. Holding speeds in the FMS provide an optimum holding speed based upon fuel burn and speed capability; but are never lower than flaps up maneuver speed.

Procedure Holding

When a procedure holding pattern is selected from the navigation database and the FMS shows PROC HOLD on the legs page, the following is true when the PROC HOLD is the active leg:

- exiting the holding pattern is automatic; there is no need to select EXIT HOLD
- if the crew desires to remain in holding a new holding pattern must be entered.

Holding Airspeeds Not Available from the FMS

If holding speed is not available from the FMS, the following speed schedule may be used temporarily. This simplified holding speed schedule may not match the FMS because the FMS holding speeds are based on many conditions that cannot be generalized into a simple schedule. However, this schedule provides a reasonable approximation of minimum fuel burn speed with appropriate margins to initial buffet.

Recommended holding speeds can be approximated by using the following guidance until more accurate speeds are obtained:

- flaps up maneuver speed approximates minimum fuel burn speed and may be used at low altitudes
- above FL250, use VREF 30 + 100 knots to provide at least a 0.3 g margin to initial buffet (full maneuver capability) when the aircraft gross weight is less than 750,000 pounds and at least a 0.2 g margin when the aircraft gross weight is greater than 750,000 pounds.

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
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Approach and Missed Approach

Chapter 5

Approach

Instrument Approaches

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.

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 MDA. 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 nav aids can be satisfied by confirming that the tuned nav aid frequency is replaced by the correct alphabetical identifier on the PFD/ND or by aurally identifying the nav aid.

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 Spec, IAP.

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, 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.



STAR/RNAV STAR Common Runway Transition Approach Clearance

If expecting a STAR or R/D (runway dependent) STAR, select the STAR approach and appropriate transition as specified in Vol. 1, SP. 11, Flight Management, Navigation.

Approach Control

- On initial contact, Approach will assign a runway. A runway assignment authorizes pilots to navigate laterally and vertically to the end of the common route and runway transition waypoint. Set the MCP altitude window to the common transition waypoint clearance limit altitude.
 - Select or verify VNAV.
- Clearance awareness is critical. Approach control may provide a “Descend via ____” clearance or a “Descend via ___, cleared ILS ____” clearance.

Note: Issuance of radar vectors after a “descend via” clearance cancels the “descend via”.

- If assigned runway is different than planned, select approach for expected runway and transition, and clean up discontinuity.

Note: Accomplish all boxed items on the Descent and Approach checklists.

- When cleared for the approach, set MCP altitude. Refer to Vol. 1, NOI.3. Using VNAV to Meet Altitude Constraints Prior to the Published FAF/PFAF/FAP.
 - Select or verify VNAV.
- Remain in LNAV until established on the final approach course.
 - Select or verify appropriate roll mode. (e.g., LOC, B/CRS)

Note: ILS transitions do not arm approach (APP) until all intermediate altitude restrictions prior to the glidepath intercept are ensured.

RNAV Visual Common Runway Transition Approach Clearance

These approaches are selectable from the FMS database with Jeppesen charts and ATTENTION ALL USERS pages. Crews will be notified via ATIS or on initial check-in with Approach Control. Pilots should not request these approaches, but when assigned, should load the approach in the FMS, select the common runway transition waypoint into the FMS, and brief the approach. Procedurally, RNAV visuals are flown much like the STAR/RNAV STAR Common Runway Transition Approach Clearance procedure.

Refer to Vol. 1, NOI.3, Charted Visual Approach Guide (Procedure in FMS Database) LNAV & VNAV Modes.



Key Phraseology

When Approach control assigns an RNAV visual approach:

- Select the appropriate approach from the database and verify all waypoints are correct.

When cleared to join the approach:

- This is an authorization to continue on the lateral portion of the procedure prior to receiving approach clearance.
- Resolve any route discontinuities between the arrival and the approach.
- Continue to fly the lateral portion of the procedure using LNAV.
- ATC will be responsible for altitude assignments.
- Comply with ATC directed descent clearances while monitoring vertical path.
- Autopilot usage required, if available.

When cleared for the approach:

- Clearance for the approach authorizes crews to fly both the lateral and vertical paths.
- Resolve any route discontinuities between the arrival and the approach.
- Situational awareness relative to the lateral and vertical path is paramount.
- Use of drag devices may be required to ensure vertical path compliance.

Missed Approach

Most RNAV visuals do not have missed approach procedures. In the event of a missed approach, ATC will issue instructions; initially fly the runway heading/trace.

Note: GPS is not required for RNAV visual approaches.

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 Spec, IAP.

Radio Altimeter

A Radio Altimeter (RA) is normally used to determine DH when a DA(H) is specified for Category II, or to determine alert height (AH) for 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. However, unless specifically authorized, the radio altimeter is not used for determining 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). However, if the radio altimeter is used as a safety backup, it should be discussed in the approach briefing.

Sidestep

Refer to the Airway Manual, Ops Spec, IAP.

Maneuver Margin

Flight profiles should be flown at, or slightly above, the recommended maneuver speed for the existing flap configuration. These speeds approximate maximum fuel economy and allow full maneuvering capability (25° bank with a 15° overshoot)

Full maneuver margin exists for all normal landing procedures whenever speed is at or above the maneuver speed for the current flap setting. Full maneuver margin exists with flaps 20 at VREF 30 + 5 during a go-around at go-around thrust.

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 and/or maximum performance unless specified differently in individual procedures. It is necessary to apply wind additives to the VREF speeds. Refer to chapter 1, Command Speeds, for an explanation of wind additives.

Landing Performance Data

The ODM FAR Dry Landing Field Length chart shows distances for flaps 25 and 30, where the Actual Landing Distance is 60% of the FAR Landing Field Lengths indicated. This chart is used for dispatch purposes. The distances are based on the following:

- the distance to a complete stop from 50 feet above the runway threshold at VREF
- maximum braking, speed brakes extended and no thrust reverse.

The ODM Operational Landing Distances table show landing distances based on runway condition/braking action and landing weight. These tables assume zero wind, four engines full reverse thrust, Speed at threshold = VREF, includes a 15% safety margin and 1,500 feet air distance from threshold to touchdown and are based on a 2,000 feet pressure altitude.

For specific charts refer to ODM, section 3.

Quick Reference Landing Length

Flap 25 or 30 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, MCO's affecting landing distance, or if above the maximum landing weight (MLW).		
Quick Reference Minimum Runway Length	747-400	
	25	30
	10,000	9,000

Assumptions:

- Airport elevation 1,000 ft or less
- Touchdown no later than 1,500 ft. from threshold
- Autobrakes 3 or higher
- Up to Max Landing Weight
- Wet or Dry runway
- Zero wind and runway slope
- Four engines at full reverse thrust

Additional stopping performance is available by:

- Selecting a higher autobrakes setting
- Increased manual braking
- Landing at a lower altitude
- Landing at a lower weight

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 20 with the gear up is acceptable.

Flap Setting for Landing

Flaps 25 Landing

When operational considerations allow, crews are encouraged to use flaps 25 for final approach and landing. Landing with flaps 25 has a minimal effect on final approach speed, landing distance, and body attitude at touchdown. Using flaps 25 for final approach and landing reduces fuel burn when compared to flaps 30.

Consider the most efficient taxi route following landing. Use normal reverse thrust. If a slight increase in landing roll will cause a longer than normal taxi, consider using a higher level of auto-brakes. In addition, carbon brake wear is largely a function of the number of application cycles and not the amount of energy dissipated (speed at which application occurs).

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. The flap extension speed schedule varies with aircraft weight and provides full maneuver capability or at least 40° of bank (25° angle of bank and 15° overshoot) to stick shaker at all weights.

Note: The entry of an airspeed greater than VREF 30 increases the entire flap speed schedule by that amount.

Stick shaker activation may occur while operating near the flap minimum maneuvering speed due to:

- operating with the speed brakes extended,
- maneuvering at or below the minimum speed for the selected flap setting, and
- maneuvering or encountering turbulence at high gross weights.

 DELTA
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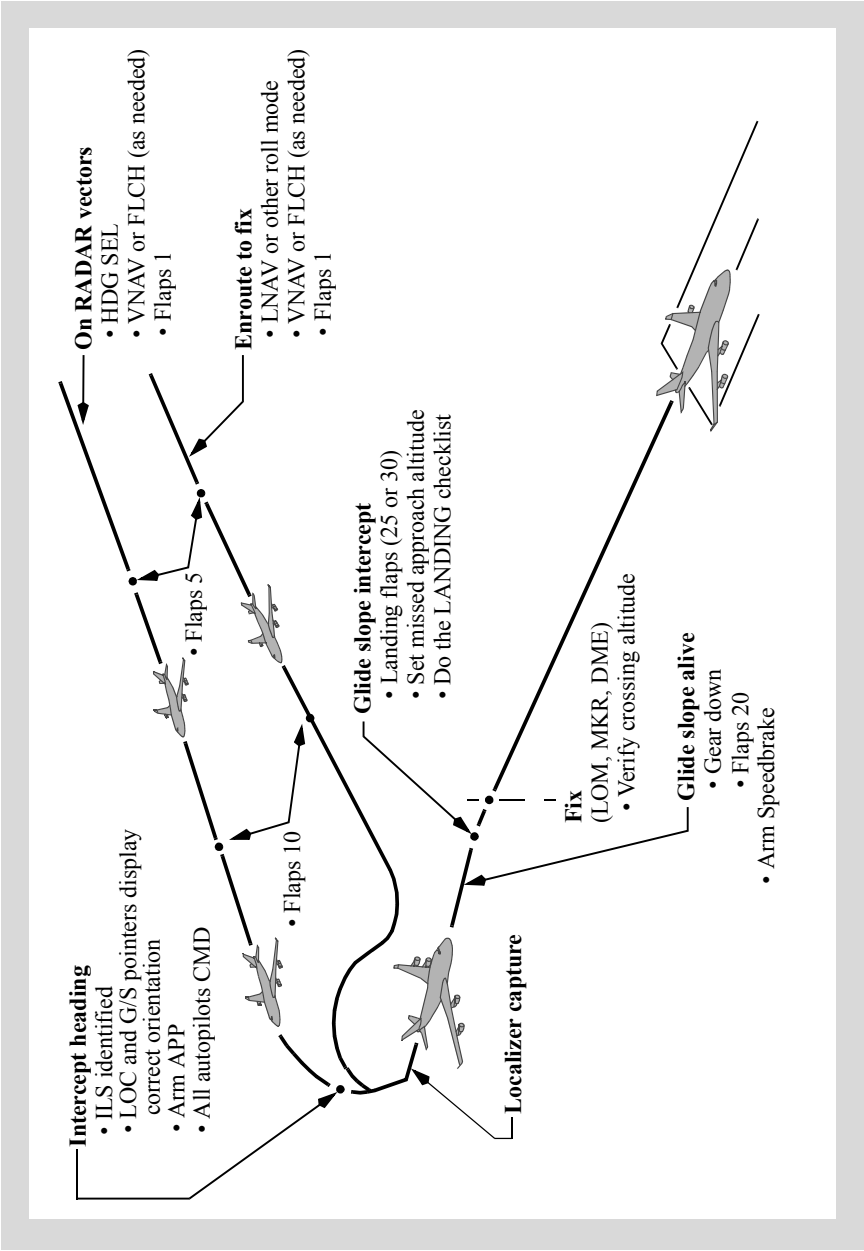
Flap Extension Schedule

Current Flap Position	At Speedtape "Display"	Select Flaps	Command Speed for Selected Flaps
UP*	"UP"	1	"1"
1	"1"	5	"5"
5	"5"	10	"10"
10	"10"	20	"20"
20	"20"	25 or 30	"VREF" + 5 knots or "VREF" + wind additive**
*Above 680,000 lbs, use UP + 20 knots.			
**When applying a wind additive, the maximum final approach speed should not exceed VREF + 20.			

Note: To determine a final approach speed with wind additives, add one-half the steady headwind component plus all of the gust value to VREF.

ILS Approach

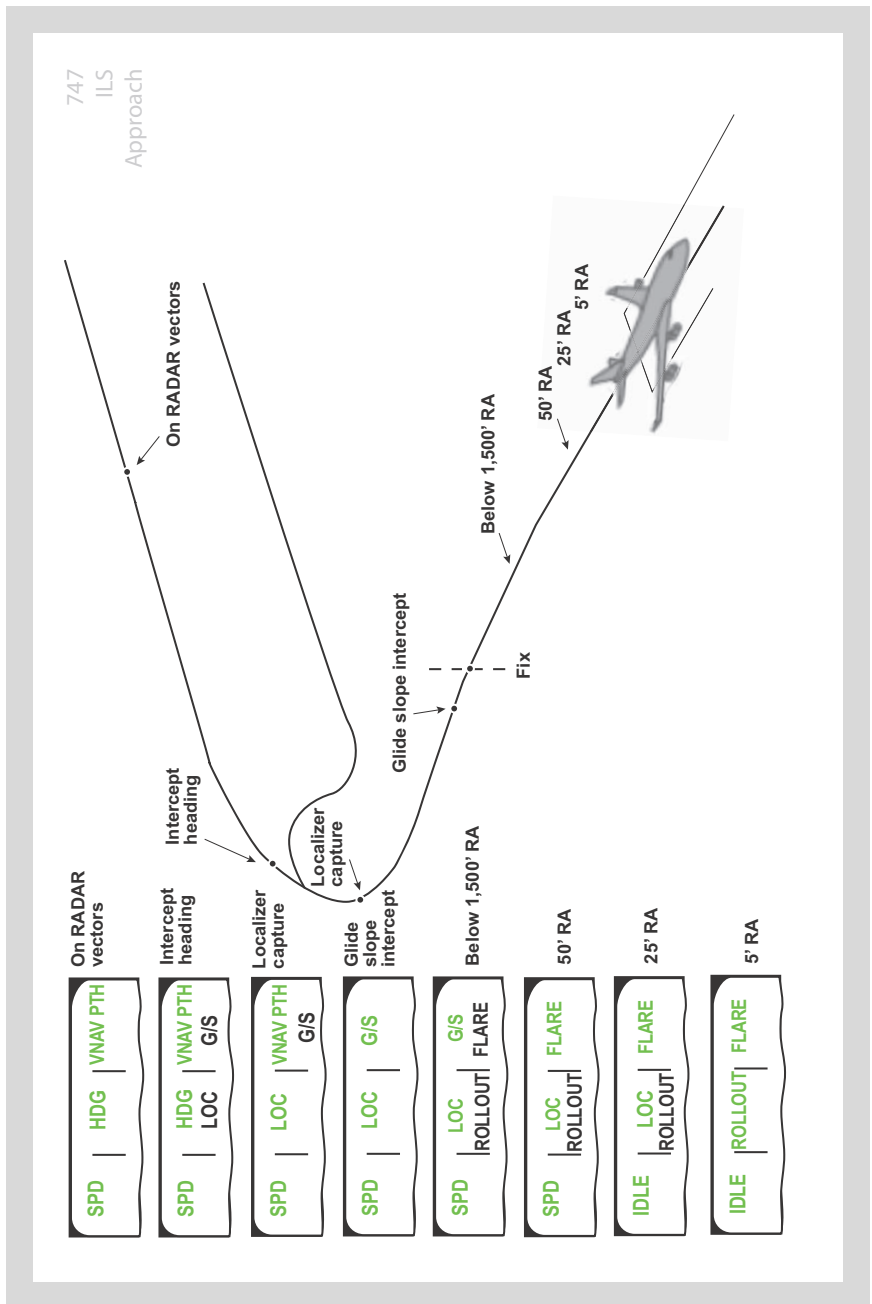
ILS Approach





747-400 Flight Crew Training Manual

FMA Progression



Low Visibility Approach Considerations (CAT II/CAT III) Expanded Approach Guide

The captain must conduct the approach.

Review the airport diagram/SMGCS chart for taxi planning.

- Low visibility taxi procedures are in effect when visibility is less than 1200 RVR.

Once established on the final approach segment of a CAT II ILS, the approach may be continued to an autoland if the controlling RVR drops below the published minimums and the required visual cues are in sight at the DA(H).

Once established on the final approach segment of a CAT III ILS, the approach may be continued to an autoland if the controlling RVR drops below the published minimums.

Applicable OM Volume 1 references:

- Autoland wind limitations, Limitations, L.10
- Standard Callouts, Introduction, NP.12
- RADIO/BARO Minimums Chart, Normal Ops Info, NOI.3

Applicable Airway Manual, Ops Specs, IAP references:

- Approach/Minima (RVR/VIS).
- Ground based equipment requirements.
- Missed approach criteria.

Applicable QRH references:

- ILS Approach Equipment Requirements Chart, NNOI.1.

Missed Approach:

A Missed Approach shall be executed for any of the following:

- The autopilot is unintentionally disengaged.
- LAND 2 or LAND 3 is not annunciated on the PFD below 1,500 feet RA on a CAT II approach.
- LAND 3 is not annunciated on the PFD below 1,500 feet RA on a CAT III approach.
- NO AUTOLAND EICAS Caution is displayed.
- NO LAND 3 EICAS Caution is displayed below 1,500 feet RA on a CAT III approach.

Note: For all other EICAS messages, aural warnings and warning/system failure flags that occur prior to alert height, the approach may be continued as long as the FMA status annunciates LAND 3 and LOC and G/S are within tolerances.



- The FMA and EICAS provide information and alerts regarding the status of the required elements of the CAT II/III airborne system.
- Reaching minimums and runway environment is not in sight on a CAT II approach.

Note: Visual contact with the runway environment is not required to continue below alert height on a CAT III approach.

- Automatic landing cannot be accomplished in the touchdown zone.

Perform Missed Approach procedures outlined in this section.

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. Displaying OFF PATH DESCENT circles on the map provides vertical flight path guidance which may assist in planning the approach.

Throughout the approach transition and approach, adjust the map display and range to provide a scaled plan view of the area.

The arrival and approach transition may be flown using HDG SEL or LNAV for lateral tracking and VNAV, FLCH, or V/S for altitude changes. VNAV is the preferred descent mode when the FMS is programmed for the intended arrival. When VNAV is not available, FLCH is the preferred descent mode for altitude changes.

If being radar vectored to the final approach and displaying the arrival procedure or approach transition is not desired, perform a DIRECT TO or INTERCEPT COURSE 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;
- LNAV capability during the missed approach procedure;

When operating in speed intervention or an autothrottle SPD mode, timely speed selections minimize thrust lever movement during the approach. This reduces cabin noise levels and increases fuel efficiency. When flaps are extended, select the next lower speed just as the additional configuration drag takes effect.

When maneuvering to intercept the localizer, decelerate and extend flaps to 5. As an option, the localizer may be intercepted at flaps 10 and flaps 10 speed. This helps prevent a localizer overshoot when using large intercept angles by providing a smaller turn radius.

Select APP 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, and
- clearance for the approach has been received.

After selecting, observe the LOC and G/S flight mode annunciations are armed.

Note: Use caution when selecting APP prior to LOC capture. If the glideslope captures prior to LOC, the AFDS will command a premature descent. False glideslope capture and subsequent climbs can also occur prior to LOC capture with APP selected while on an intercept heading. To avoid unwanted/premature glideslope capture, VOR/LOC may be selected initially, followed by APP once established on the localizer.

The glideslope may be captured from either above or below.

When using LNAV to intercept the final approach course, ensure raw data indicates localizer interception to avoid descending on the glideslope with LOC not captured. 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.

Final Approach

At localizer capture, the heading bug automatically slews to the inbound course. For normal localizer intercept angles, very little overshoot occurs. Bank angles up to 30° may be commanded during the capture maneuver. For large intercept angles 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 begins to move (glideslope alive), extend the landing gear, select flaps 20 and decrease the speed to flaps 20 speed. Extension of landing flaps at speeds in excess of flaps 20 speed may cause flap load relief activation and large thrust changes.

At glideslope capture, observe the flight mode annunciations for correct modes. At this time, select landing flaps and VREF + 5 knots or, if landing with the autothrottles off, VREF + 5 knots or VREF + wind additive, and do the Landing checklist. The pilot monitoring should continue standard callouts during final approach and the pilot flying should acknowledge callouts.

Check for correct crossing altitude when crossing the final approach fix (FAF or OM).

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.

Autoland

The pilots should monitor the quality of the approach, flare, and landing, including speedbrake deployment and autobrake application.

Below 1,500 feet radio altitude, the flare and rollout modes are armed. The autoland status annunciation should display LAND 3 or LAND 2. As the lowest weather minimums are directly related to the system status, both pilots must observe the autoland status annunciation.

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.

During an autoland with crosswind conditions, the runway alignment maneuver uses forward slip to reduce the crab angle of the aircraft at touchdown. Alignment begins at 500 feet radio altitude or lower, depending on the strength of the crosswind. The amount of forward slip induced is limited to 5°. When a strong crosswind is present, the aircraft does not fully align with the runway, but lands with a slight crab angle. In all cases, the upwind wing is low at touchdown. The autopilot and autobrakes should remain engaged until a safe stop is assured and adequate visibility exists to control the aircraft using visual references.

Decision Altitude or Height - DA(H)

A Decision Altitude or Height is a specified altitude or height in an ILS or some approaches using a VNAV path where a missed approach must be initiated if the required visual reference to continue the approach has not been established. The “Altitude” value is typically measured by a barometric altimeter and is the determining factor for minima for Category I approaches, (e.g., ILS, or RNAV with VNAV). The “Height” value specified in parenthesis, typically an RA height above the touchdown zone (HAT), is advisory. The RA may not reflect actual height above terrain.

For most Category II and all fail passive 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.

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.

Alert Height - AH

Alert heights are used for fail operational Category III operations. Alert height is a height above the runway, above which a Category III approach must be discontinued and a missed approach initiated if a specified failure occurs. For a discussion on specified failures, see the Faults section, this chapter. Radio altimeters are set to an alert height to assist in monitoring autoland status. Most regulatory agencies do not require visual references below alert height.

Descent Below Decision Altitude or Height - DA(H)

Refer to the Airway Manual, Ops Spec, IAP.

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 the Airway Manual, Ops Spec, IAP.

Visual References

Refer to the Airway Manual, Ops Spec, IAP.

Category III operations using fail operational autoland systems normally do not require specific visual references below AH.

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; QRH, NNOI.1; or MDM for specific systems and equipment needed for Category II and Category III operations.

Category II Operations

The aircraft is certified to conduct Category II approaches using single or multiple autopilots, or flight director only, with three or four engines; however, Delta Air Lines requires a minimum of two operative autopilots, one operative flight director, and four operative engines.

Category III Operations

Category III operations are based on an approach to touchdown using the automatic landing system. The airplane has been demonstrated to meet Category III criteria with four or three engines operating for flaps 25 or 30 landing.

Autoland Capabilities

Refer to the applicable Vol. 1 limitations for AFDS limitations and a description of demonstrated autoland capabilities.

Note: For autoland use flaps 25 or 30.

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

Fail operational refers to an autoflight system capable of completing an ILS approach, autoland, and rollout following the failure of any single system component after passing alert height. Fail operational is displayed on the PFD as LAND 3.

Fail Passive

Fail passive refers to an autoflight system which, in the event of a failure, causes no significant deviation of aircraft flight path or attitude. Fail passive is displayed on the PFD as LAND 2. A DA(H) is used as approach minimums.

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 thrust levers) throughout automatic approaches and landings. Be prepared to disengage the autopilot and manually land or go-around.

The AFDS includes a monitor to detect significant ILS signal interference. If localizer or glideslope signal interference is detected by the monitor, the autopilot disregards erroneous ILS signals and remains engaged in an attitude-stabilizing mode based on inertial data. Most ILS signal interferences last only a short time, in which case there is no annunciation to the flight crew other than erratic movement of the ILS raw data during the time the interference is present. No immediate crew action is required unless erratic or inappropriate autopilot activity is observed.

If the condition persists, it is annunciated on the PFD. If the autopilot is engaged, annunciations alert the flight crew that the autopilot is operating in a degraded mode and the aircraft may no longer be tracking the localizer or glideslope. When the condition is no longer detected, the annunciations clear and the autopilot resumes using the ILS for guidance.

Autolands on Contaminated Runways

AFDS 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 AFDS approach to a manual approach can be accomplished anytime during the ILS 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.

Intercepting Glideslope from Above

The following technique may be used for ILS approaches, however it is not recommended for approaches using VNAV.

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.

The following technique will help the crew intercept the G/S safely and establish stabilized approach criteria by 1,000 feet AFE:

- Select APP on the MCP and verify that the G/S 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 and flap load relief activation. 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. Comply with the recommendations on the use of speedbrakes found in chapter 4 of this manual.

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, even in VMC conditions.



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 or flaps maneuvering 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

Faults leading to non-normal operations can be divided into two categories:

- those occurring above AH
- those occurring at or below AH.

Within these categories many non-normal situations or scenarios are possible. The flight deck is designed so that a quick analysis and decision can be made for virtually all non-normal or fault situations using the crew alerting system and autoland status annunciation.

If the flight crew is aware of the airplane equipment requirements for the approach, the following can be used for any AFDS fault indication:

Above Alert Height

Immediately after recognizing the fault from the crew alerting system, instrument flags, or engine indications, check autoland status annunciation.

- if the autoland status annunciation has not changed, and the equipment is not required for the approach or can be switched, (e.g., flight director), continue the approach
- if the autoland status annunciation has changed, or the equipment is required for the approach, adjust to the appropriate higher minimums or go-around. However, if suitable visual reference is established, consider landing.

At or Below Alert Height

A thorough fault analysis was included as a part of the fail operational certification. Below 200 feet AGL a safe landing and rollout can be made with any probable failure conditions.

Flight crew alerts (messages, lights, or aural) may occur at any time during the approach. If a master caution or warning (amber or red light illuminated with the associated aural) occurs below alert height, do not disengage the autopilot unless the autopilot system is not controlling the airplane adequately. Below alert height, multiple autopilots protect against any probable system failure and will safely land the airplane. For any EICAS caution level alert, continue the approach to an automatic landing and rollout unless the alert is accompanied by a master caution. The pilot should not intervene below AH unless it is evident that pilot action is required. If a fault affects the autobrakes, assume manual control of braking. Accomplish related procedures for system faults after rollout is complete and manual control of the airplane is resumed.

If the autopilot is unintentionally disengaged below alert height, the landing may be completed if suitable visual reference is established.

If a go-around is initiated with the autopilot disengaged, press the TO/GA switch. If the TO/GA switch is not pressed, the flight directors remain in the approach mode.

Raw Data - (No Flight Director)

Raw data approaches are normally used during training to improve the instrument scanflow. If a raw data approach is required during normal operations, refer to the MDM and/or QRH, NNOI, section 1, ILS Approach Equipment Requirements for the possibility of increased landing minima.

ILS deviation is displayed on the attitude display. ILS deviation may also be displayed on the ND by selecting APP mode on the EFIS Control Panel. The localizer course deviation scale on the attitude display remains normal scale during the approach and does not change to expanded scale at approximately 5/8 dot, as happens with F/D and/or autopilot engaged and localizer captured. Continue to crosscheck the map display against the attitude display raw data. Select VOR/ADF switches to display appropriate pointers on the ND.

The magnetic course/bearing information from the VOR/ADF pointers on the navigation display may be used to supplement the attitude display localizer deviation indication during initial course interception. Begin the turn to the inbound localizer heading at the first movement of the localizer pointer.



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 localizer pointer 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), lower the landing gear, extend flaps 20, and decelerate to flaps 20 speed. Intercepting the glideslope, extend landing flaps, and establish the final approach speed. When established on the glideslope, preset the missed approach altitude in the altitude window. On final approach, maintain VREF + 5 knots or an appropriate correction for headwind component. Check altitude crossing the FAF. Begin timing, if required. 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 automatic ILS approach procedures. Select APPR after being cleared for the approach.
- 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

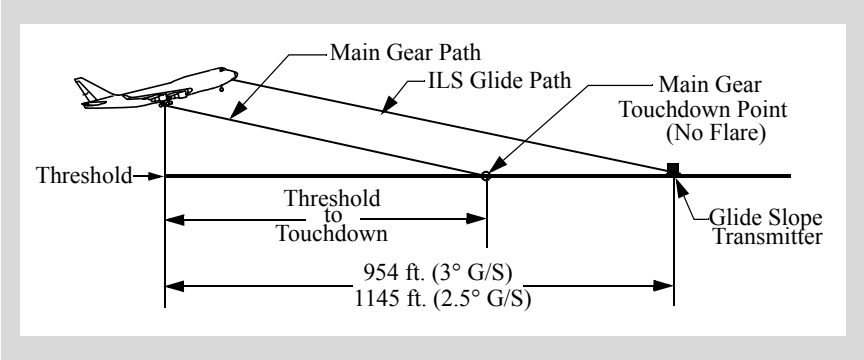
When breakout instructions are issued, it is important to initiate a turn without delay. This is accomplished more quickly by selecting the AP and FD off and hand flying the turn. The bank angle should not exceed 30°.

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.

ILS Approach - Landing Geometry

The following diagrams use these conditions:

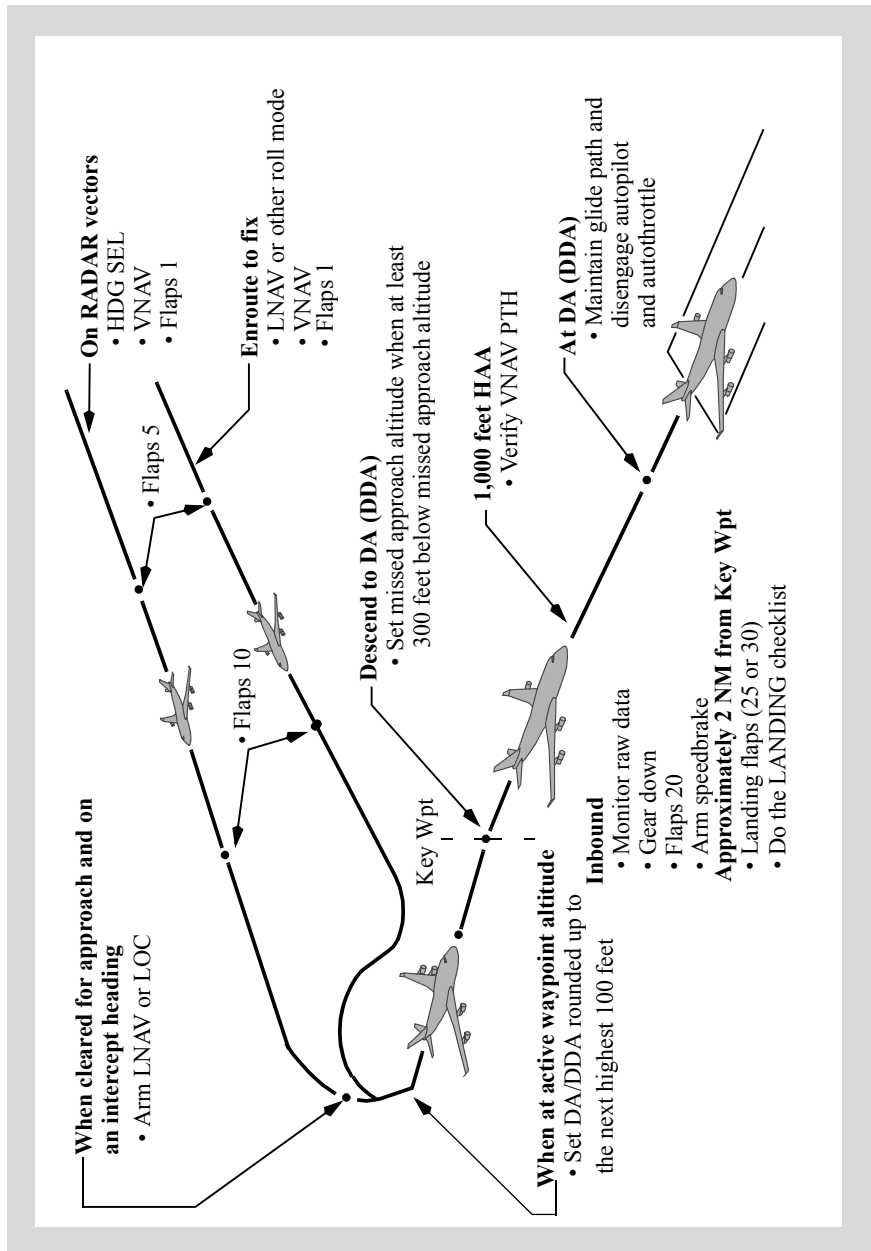
- Data is based on typical landing weight.
- Aircraft body attitudes are based on flaps 30, VREF 30 + 5, and should be reduced by 1° for each 5 knots above this speed.
- Pilot eye height is measured when the main gear is over the threshold.
- Aircraft ILS antenna crosses threshold at 50 feet.



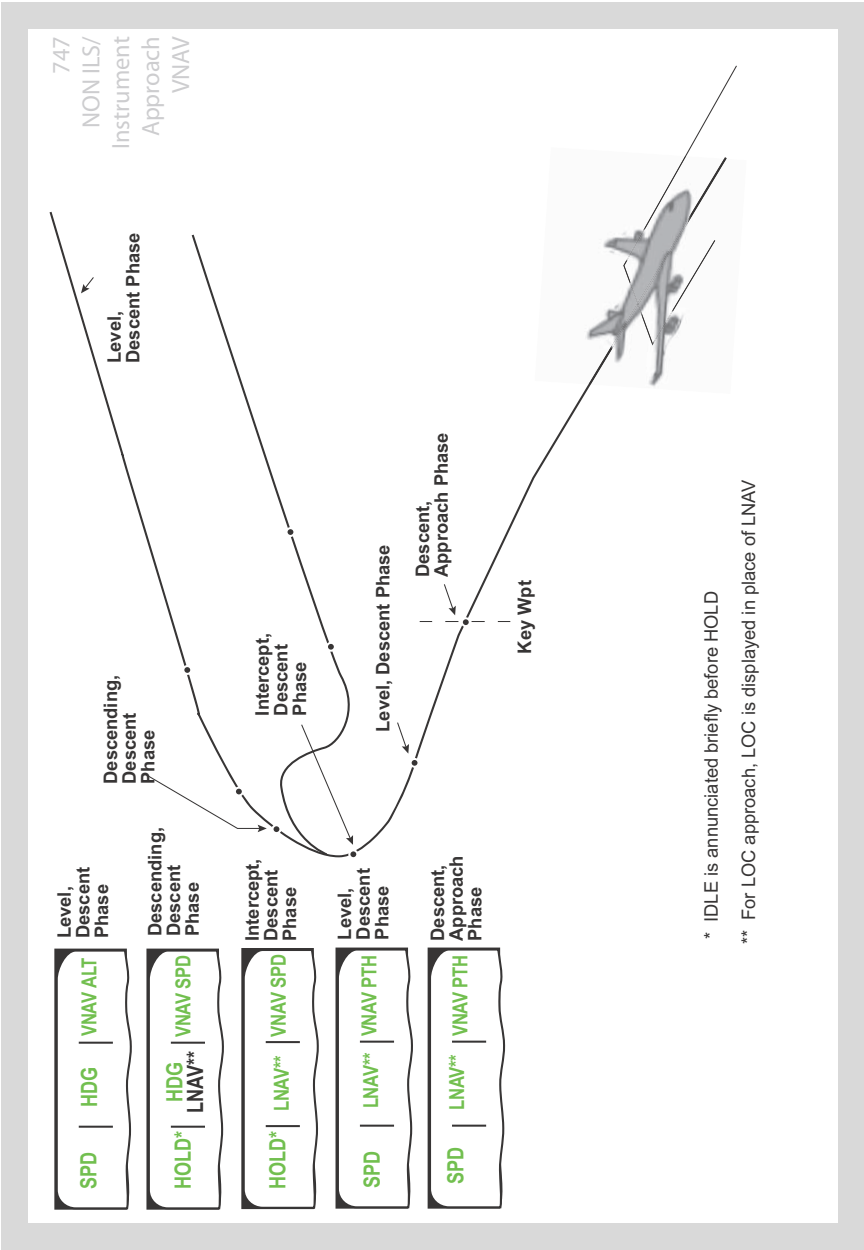
Flaps 30		Main Gear over Threshold		Threshold to Main Gear Touchdown Point - No Flare (feet)
Glide Path (degrees)	Airplane Body Attitude (degrees)	Pilot Eye Height (feet)	Main Gear Height (feet)	
2.5	2.5	67	31	701
3.0	2.0	66	31	584

Non - ILS Instrument Approaches

Non-ILS Instrument Approach Using VNAV Profile



FMA Progression





GPS, RNAV (GPS), or RNAV (GNSS)

Approach Considerations

Expanded Approach Guide

LNAV & VNAV Modes

For approaches with inoperative equipment refer to QRH. Non-Normal Ops Info tab, RNAV Approach Equipment Requirements.

Airport temperature..... Confirm within limits

Jeppesen approach plate temperature restrictions apply to LNAV/VNAV minimums. If the airport temperature is colder than the published range, the approach is not allowed. If the temperature is higher than the published range, use LNAV minimums.

Local altimeter Verify available

LNAV/VNAV minimums are not authorized with a remote altimeter setting. when a remote altimeter source is authorized, RNAV approaches should be conducted to LNAV minimums.

Autopilot Required in IMC

For any non-ILS approach flown in IMC conditions, use of the autopilot and autothrottle (if operational) are required until visual contact with the runway can be maintained, or upon arrival at the DA/DDA, whichever occurs first.

FMS approach procedure Select and verify

CAUTION: RNAV (RNP) approaches are not authorized.

All RNAV approaches must be selectable from the FMS navigational database. Crews may not change a published RNAV approach (e.g., RNAV (GPS) Y Rwy 31L) and attempt to fly a different RNAV approach (e.g., RNAV (GPS) X Rwy 31L). Waypoints between the FAF/FAP and runway/MAP must not be modified. To minimize mistakes, flight crews should compare waypoints, courses, and distances. All courses published in the FMS database and on the Jeppesen approach plate must agree within 3°. In addition, flight crews should ensure that the glide path angle (GP) is displayed.

When multiple RNAV approaches exist to the same runway (e.g. KJFK), crewmembers must verify that the approach selected in the FMS database and the approach in the ATC clearance are identical. This verification step is important for several reasons. First, only one RNAV approach is published per runway. Second, only six characters are used in CDU approach names. Finally, alphabetical suffixes (X, Y, and Z), which are published on Jeppesen approach plates, are not used in FMS approach naming conventions (e.g., RNV 31L).

Database waypoint constraint altitudes may be modified as directed by ATC.

Cold weather altitude corrections should be applied anytime the field temperature is less than -10°C. See Airway Manual, Ops Specs, IAP.

RNAV circling approaches are authorized. See Circling Maneuver, Volume 1, Normal Operational Information chapter.

Key Waypoint Enter

The 747 FMS transitions from VNAV Descent Phase to VNAV Approach Phase when crossing a specific database waypoint (normally the first waypoint in the FMS database approach). We refer to this waypoint as the Key Waypoint. To determine the Key Waypoint:

- Select the RTE page
- Identify the selected approach in the VIA column
- Identify the waypoint that is immediately right of the selected approach located in the TO column
- Key Waypoint is located directly above the waypoint identified in the TO column
- Select Key Waypoint to the scratchpad
- Enter Key Waypoint on the FIX page

Note: Conditional Waypoints (INTCP) cannot be entered on the FIX page. If desired for situational awareness, the next closest fix to the runway may be entered.

Note: If the aircraft is vectored inside the original Key Waypoint, extending a line into the next waypoint will change the key Waypoint and delay approach phase logic. In this case it is not necessary to change the waypoint entered on the FIX page.

Approach RNP Set 0.3

The Required Navigational Performance (RNP) does not automatically change to 0.3 until passing the Key Waypoint. Manually setting 0.3 allows completion of this step prior to beginning the approach. Set the RNP value to 0.3 on POS REF page 2/3. Do not conduct the approach if EICAS message UNABLE RNP is displayed.



GPS updating Confirm

Verify “GPS” is displayed on either POS REF 2/3 or the ND.

Minimums Set DA

CAUTION: Do NOT use LPV minimums.

Use LNAV/VNAV minimums, and set published, DA (worldwide).

If LNAV/VNAV minimums are not published, or can’t be used due to temperature or local altimeter limitations, use LNAV minimums and set DDA (MDA+50’, worldwide).

If neither LNAV/VNAV nor LNAV minimums are available, use published MDA and set DA (within 50 United States and its associated territories) or DDA (MDA+50’, outside the 50 United States and its associated territories).

XTK & VTK error Monitor

Pilot intervention with HDG SEL is NOT authorized.

Both pilots should display Map Mode on their ND.

Crews must monitor vertical track (VTK) and cross track (XTK) data when the aircraft is descending on the path and inside the FAF. VTK and XTK data can be monitored on PROG page 2. VTK data can also be monitored on the Vertical Path indicator on the ND.

The Pilot Monitoring will immediately report to the Pilot Flying any deviations that exceed the following parameters when established on the final approach course of a RNAV or GPS approach:

- Course deviation of 0.3nm
- Vertical deviation of +100/-50 feet

Raw data (optional for situational awareness only) Tuned

When using RNAV procedures, the FMS is the primary navigation reference and ground-based navaids are not required. If a relevant navaid is operational, it may be tuned, identified, and monitored throughout the approach. This increases the situational awareness and may identify a database error. Tune appropriate navaids on the NAV/RAD page and use the VOR/ADF switches to display appropriate raw data on the ND. If the navaid(s) subsequently become inoperative, continue the approach as long as the FMS instructions are valid.

Prior to beginning the approach:

VNAV Verify or select

Prior to beginning the approach, verify a VNAV mode is engaged on the FMS (VNAV PATH, VNAV ALT, or VNAV SPD). If a VNAV mode is not engaged:

- insert current airspeed on the active VNAV page
- press MCP VNAV button and confirm engagement on the FMA

Speed intervention Set

Push MCP IAS/MACH selector and verify the IAS/MACH window opens.

Set desired speed.

When cleared for the approach:

LNAV Select

Verify that the correct active waypoint is displayed on the LEGS page or ND.

When:

- established on a published segment of the approach, or
- vectored to a final approach course intercept heading and level at the active waypoint altitude, or
- cleared direct to an approach waypoint and level at that waypoint altitude:

DA/DDA Set

Set DA/DDA, rounded up to the next higher 100 feet, in the MCP ALT window.

If VNAV ALT is displayed AND aircraft more than 150 feet above the next constraint:

MCP Altitude knob Push one time

Pressing the MCP ALT knob will initiate a descent from VNAV ALT and allow VNAV PATH to be captured.

WARNING: Do not push the MCP Altitude knob if the airplane altitude is within 150 feet of an altitude constraint (large font altitude on the LEGS page). An early descent and loss of terrain separation may occur! In this situation, flight crews should delay pushing the MCP altitude knob until reaching the constrained waypoint.

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CAUTION: More than one push of the MCP Altitude knob may delete subsequent constraints. After pushing the MCP Altitude knob, verify the next altitude constraint on the LEGS page is not removed.

Altimeters..... Check within 100 feet by FAF

Prior to the FAF/FAP, the captain and first officer altitude displays must agree within +/-100 feet. do not continue a RNAV or GPS approach if this crosscheck fails.

Inside the Key Waypoint, no later than 1,000 feet AGL and a least 300 feet below missed approach altitude:

Missed approach altitude.....Set

Set lowest initial level off altitude on missed approach procedure in the MCP ALT window.

No later then 50 feet below DA:

Autopilot Disengage

Execute a missed approach with the approach lights or runway environment not in sight if any of the following occur:

- criteria listed in the Airway Manual, Ops Specs, IAP
- VERIFY POSITION FMS message
- UNABLE RNP EICAS message,
- GPS EICAS message (dual failure only),
- XTK error greater then 0.3 (PROG page 2),
- dual FMS failure,
- additionally, after the FAF with approach lights or runway environment not in sight:
 - VTK error exceeds +100/-50 feet,
 - loss of VNAV PTH below 1,000 feet AGL,
 - either FMS fails, or
 - VNAV fails

ILS (GS Out), LOC, LDA, VOR Approach Considerations

Expanded Approach Guide

LNAV or LOC & VNAV Modes

Autopilot Required in IMC

For any non-ILS approach flown in IMC conditions, use of the autopilot and autothrottle (if operational) are required until visual contact with the runway can be maintained, or upon arrival at the DA/DDA, whichever occurs first.

FMS approach procedure Select and verify

To fly a non-ILS approach using VNAV, the approach must be selectable from the FMS navigation database. Building the approach is not authorized. When multiple approaches, or the same type exist to the same runway (e.g. KJFK), crewmembers must verify that the approach selected in the FMS database and the approach in the ATC clearance are identical.

Note: If assigned and ILS approach with the glideslope inoperative, select the applicable ILS approach from the FMS ARRIVALS page. The FMS database will only contain LOC approaches for localizer-only procedures.

If conducting an ILS approach with the glideslope inoperative, ensure that the altitudes on the FMS LEGS page coincide with the LOC portion of the approach. If the FMS LEGS page altitude for the LOC final approach fix/final approach point (FAF/FAP) waypoint does not coincide with the charted altitude, manually modify the FAF/FAP waypoint altitude to agree with the charted value. Do not modify any instrument procedure waypoint altitudes inside the FAF/FAP. After any modification, always verify that the construction of the approaches utilizes a VNAV flight path angle that ensures compliance with all crossing restrictions.

Key Waypoint Enter

The 747 FMS transitions from VNAV Descent Phase to VNAV Approach Phase when crossing a specific database waypoint (normally the first waypoint in the FMS database approach). We refer to this waypoint as the Key Waypoint. To determine the Key Waypoint:



- Select the RTE page
- Identify the selected approach in the VIA column
- Identify the waypoint that is immediately right of the selected approach located in the TO column
- Key Waypoint is located directly above the waypoint identified in the TO column
- Select Key Waypoint to the scratchpad
- Enter Key Waypoint on the FIX page

Note: Conditional Waypoints (INTCP) cannot be entered on the FIX page. If desired for situational awareness, the next closest fix to the runway may be entered.

Note: If the aircraft is vectored inside the original Key Waypoint, extending a line into the next waypoint will change the Key Waypoint and delay approach phase logic. In this case it is not necessary to change the waypoint entered on the FIX page.

When using LNAV:

Approach RNP Set 0.3

Required Navigational Performance (RNP) does not automatically change to 0.3 until passing the Key Waypoint. Setting 0.3 manually allows completion of this step prior to beginning the approach. When using LNAV as the roll mode, set the RNP value to 0.3 on the POS REF page 2/3. Do not conduct the approach if EICAS message UNABLE RNP is displayed.

Minimums Set DA/DDA

Crews may use the published MDA as a DA for approaches flown in the 50 United States or its associated territories. Outside these areas, all VOR or localizer-based approaches must be flown to a DDA (MDA + 50 feet).

Raw data and VTK error Monitor

For raw data monitoring and situational awareness, all available nav aids should be tuned on the NAV RAD page and displayed on the PFD/ND.

Crews must monitor lateral track (LTK) raw data when the aircraft is established on the final approach course. LTK raw data monitoring can be accomplished by:

- VOR - Monitoring the final approach course by selecting the VOR switch, the VOR Mode selector, and/or the POS switch on the EFIS Control Panel. the VOR bearing pointer, CDI, and/or radials will be displayed on the ND.
- LOC - Monitoring the localizer course on the PFD.

Crews must monitor vertical track (VTK) raw data when the aircraft is descending on the path inside the FAF/FAP. VTK raw data can be monitored on the Vertical Path indicator on the ND or on PROG page 2 of the CDU.

Pilot intervention in HDG SEL is not authorized

The Pilot Monitoring will immediately report to the Pilot Flying any deviations that exceed the following parameters:

- course deviation of 2.5° or 1/2 dot from the VOR radial, or 1/2 dot from a localizer course
- VTK error exceeds +/-75 feet

Prior to beginning the approach:

VNAV..... Select or verify

Before beginning the approach verify that a VANV mode is engaged on the FMS (VNAV PATH, VNAV ALT, or VNAV SPD). If a VNAV mode is not engaged:

- insert current airspeed on the active VNAV page
- press MCP VNAV button and confirm engagement on the FMA

Speed intervention..... Set

Push MCP IAS/MACH selector and verify the IAS/MACH window opens.

Set desired speed.

When cleared for the approach:

LNAV or LOC..... Select

Select LNAV for a VOR approach, LOC for a LOC, LDA, or ILS (GS inop). Verify that the correct active waypoint is displayed on the LEGS page or ND.

When:

- established on a published segment of the approach, or
- vectored to a final approach course intercept heading and level at the active waypoint altitude, or
- cleared direct to an approach waypoint and level at that waypoint altitude:

DA/DDA Set

Set DA/DDA rounded up to the next higher 100 feet, in the MCP ALT window.



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If VNAV ALT is displayed AND aircraft more than 150 feet above the next constraint:

MCP Altitude knob Push one time

Pressing the MCP ALT knob will initiate a descent from VNAV ALT and allow VNAV PATH to be captured.

WARNING: Do not push the MCP Altitude knob if the airplane altitude is within 150 feet of an altitude constraint (large font altitude on the LEGS page). An early descent and loss of terrain separation may occur! In this situation, flight crews should delay pushing the MCP altitude knob until reaching the constrained waypoint

CAUTION: More than one push of the MCP Altitude knob may delete subsequent constraints. After pushing the MCP Altitude knob, verify the next altitude constraint on the LEGS page is not removed.

Inside the Key Waypoint, no later than 1,000 feet AGL and at least 300 feet below missed approach alt:

Missed approach altitude Set

Set lowest initial level off altitude on missed approach procedure in the MCP ALT window.

No later than 50 feet below DA or 100 feet below DDA:

Autopilot Disengage

Execute a missed approach after the FAF with the approach lights or runway environment not in sight of any of the following occur:

- criteria listed in the Airway Manual, Ops Specs, IAP
- loss of VNAV PTH below 1,000 feet AGL,
- vertical path deviation exceeds +/-75 feet, or
- raw data limits exceeded

Additional Considerations:

When LNAV engaged:

- UNABLE RNP EICAS message

General

Non-ILS approaches are defined as:

- RNAV approach - an instrument approach procedure that relies on aircraft area navigation equipment for navigational guidance. The FMS is FAA-certified RNAV equipment that provides lateral and vertical guidance referenced from an FMS position. The FMS uses multiple sensors (as installed) for position updating to include GPS, DME-DME, VOR-DME, LOC-GPS, and IRS.
- 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 in the same way as an RNAV approach until reaching the visual segment.
- GPS approach - an approach designed for use by aircraft using stand-alone GPS receivers as the primary means of navigation guidance. However, aircraft using FMS as the primary means of navigational guidance, have been approved by the FAA to fly GPS approaches provided an RNP of 0.3 or smaller is used.
- VOR approach
- NDB approach
- LOC, LOC (BACK CRS), LDA or similar approaches.

Note: The 747-400 aircraft are not currently approved for RNAV (RNP) operations.

Non-ILS approaches are normally flown using VNAV. The use of FLCH is not recommended after the FAF. Recommended roll modes are provided in the applicable Vol. 1 procedure.

Non - ILS Instrument Approaches - General

The following sections describe methods for flying non-ILS Continuous Descent Final Approach (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 VNAV, as illustrated, 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

VNAV is the preferred method for accomplishing non-ILS approaches that have an appropriate vertical path defined on the FMC LEGS page. The section on Use of VNAV provides information for obtaining an appropriate path, including published glide paths.

Use of the Autopilot During Approaches

Automatic flight is the required method of flying non-ILS approaches in IMC conditions.

Note: Currently, the VNAV PTH mode contains no path deviation alerting. For this reason, the autopilot should remain engaged until suitable visual reference has been established.

Raw Data Monitoring Requirements

When conducting non-ILS VNAV approaches, crews must monitor lateral track (LTK) raw data when the aircraft is established on the final approach course. LTK raw data monitoring can be accomplished by:

- VOR - monitoring the final approach course by selecting the VOR switch, the VOR Mode selector, and/or the POS switch on the EFIS Control Panel. The VOR bearing pointer, CDI, and/or radials will be displayed on the ND.
- LOC - monitoring the localizer course with the localizer diamond on the PFD.

Crews must monitor vertical track (VTK) raw data when the aircraft is descending on the path, inside the Key Waypoint. VTK raw data can be monitored on the Vertical Path indicator on the ND or on PROG page 2 of the FMC.

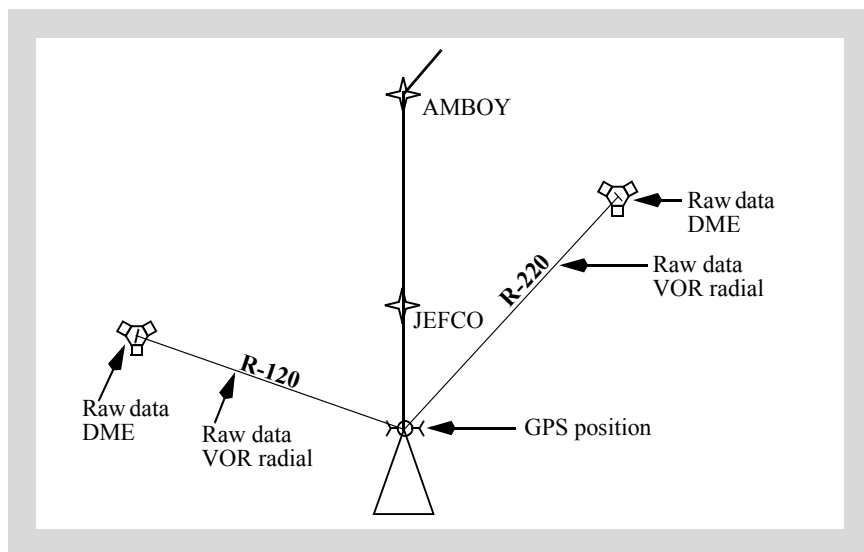
The PM will immediately report to the PF any deviations that approach and/or exceed the following parameters:

- Course deviation: 2 1/2 degrees or 1/2 dot from VOR radial, or 1/2 dot from a localizer course.
- Vertical deviation: +/- 70 feet inside the Key Waypoint and at DA/DDA.

The PF will execute an immediate missed approach if the aircraft exceeds the lateral or vertical limits unless flight conditions are VMC, the landing runway is in sight, and the aircraft is in a position to make a normal landing.

Typical Navigation Display

The following diagram represents a typical navigation display with the POS display selected.



MAP Displays and Raw Data

The map mode should be used to the maximum extent practicable. The map display provides a plan view of the approach, including final approach and missed approach routing. The map increases crew awareness of progress and position during the approach.

The map is particularly useful when the inbound course does not align with runway centerline and allows the pilot to clearly determine the type of alignment maneuver required. The map can be used to integrate weather radar returns, terrain or traffic information within the approach path and airport area.

Note: When appropriate, compare aircraft position on the map with ILS, VOR, DME, and ADF systems to detect possible map shift errors. Use of the POS function selectable on the EFIS control panel is the recommended method for making this comparison. The VOR and ADF pointers should be displayed on the map.

RNAV Approaches

RNAV approaches may be flown provided the RNP being used is equal to or less than the RNP specified for the approach and is consistent with the Vol. 1 approach guide specified RNP value.



Use of LNAV

To use LNAV 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

- This method is required for RNAV and GPS approaches. 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 ILS GS OUT approach, an ILS procedure might be selected if the plan view (route) is identical to the ILS 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

- Due to potentially inadequate terrain clearance, manual waypoint entry should not be accomplished for RNAV or GPS approaches.
- Manual waypoint entry may not be accomplished when using VNAV after the FAF.
- 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 INTERCEPT COURSE 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.

LNAV 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. A similar display may be created by manually tuning an appropriate VOR and selecting the desired course. These methods provide reference information on the map display only. They are not reflected on the LEGS page and cannot be tracked with LNAV. These methods 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.

Note: Automatic procedure tuning and VNAV PTH operation using speed intervention is not available with manually entered waypoints.

If the approach is not available in the navigation database, select the landing runway from the FMS arrivals page. The runway and associated extended centerline then displays on the map to aid in maintaining position awareness.

Pilots should not become involved in excessive “heads down” FMS manipulation to build map displays while at low altitude. Raw data VOR, ADF, and ILS displays should be used to avoid distractions during higher workload phases of flight. Map building should be avoided below 10,000 feet AGL.



Use of VNAV

Approaches using VNAV may be accomplished using any of the recommended roll modes provided in Vol 1.

A vertical path suitable for use of VNAV is one that approximates 3° and crosses the runway threshold at approximately 50 feet. To obtain such a VNAV path, maximum use of the navigation database is recommended. For approaches where an RNP is specified, or approaches where a DA(H) is used, the waypoints in the navigation database from the FAF onward may not be modified except to add a cold temperature correction, when appropriate, to the waypoint altitude constraints.

Approaches with a glide path (GP) angle displayed on the final approach segment of the LEGS page are completely compatible with VNAV and comply with final approach step-down altitudes (minimum altitude constraints).

ILS approaches coded with the appropriate threshold crossing height may be used as an overlay for another approach such as LOC.

VNAV should be used only for approaches that have the following features:

- a published GP angle on the LEGS page for the final approach segment,
- an RWxx waypoint coincident with the approach end of the runway, or
- a missed approach waypoint before the approach end of the runway, (e.g., MXxx).

These features permit construction of a normal glide path. VOR approaches with the missed approach point on the LEGS page beyond the runway threshold and circling only approaches do not have these features.

With the autopilot engaged, the EICAS alert message AUTOPILOT and VNAV mode fail indications are available to alert the flight crew of potential problems with the flight path.

When appropriate, make cold temperature altitude corrections by applying a correction from an approved table to the waypoint altitude constraints. The FMS obtains the GP angle displayed on the LEGS page from the navigation database. This GP angle is based on the standard atmosphere and is used by the FMS to calculate the VNAV path which is flown using a barometric reference. When OAT is lower than standard, true altitudes are lower than indicated altitudes. Therefore, if cold temperature altitude corrections are not made, the effective GP angle is lower than the value displayed on the LEGS page. When cold temperature altitude corrections are made, VNAV PTH operation and procedure tuning function normally; however, the aircraft follows the higher of the glide path angle associated with the approach (if available) or the geometric path defined by the waypoint altitude constraints.

When on final approach, VNAV should be used with speed intervention active to reduce workload. Adding speed constraints to the final approach waypoints is normally not needed and causes extra workload without providing any safety benefit. This also reduces the ability to make last minute approach changes. However, if needed, speed constraints may be changed if the default value is not suitable.

To prevent unnecessary level offs while descending in VNAV, set the MCP altitude selector to the DA/DDA rounded up to the nearest 100 feet when:

- established on a published segment of the approach, or
- vectored to a final approach course intercept heading and level at the active waypoint altitude, or
- cleared direct to an approach waypoint and level at that waypoint altitude.

Use of Altitude Intervention During Approaches Using VNAV

Altitude intervention is appropriate during approaches only if the AFDS enters VNAV ALT mode above the approach path and descent must be continued. Entering VNAV ALT mode can occur if passing a waypoint on the approach and the crew has failed to reset the MCP altitude to a lower altitude. If this occurs, set the MCP altitude to the next lower altitude constraint or DA/DDA rounded to the nearest 100 feet, as appropriate, and select altitude intervention. When VNAV altitude intervention is selected, VNAV path deviation indications on the map display disappear momentarily while the path is recalculated.

If altitude intervention is selected when on-approach logic is active, typically after the aircraft has sequenced the first approach waypoint, level flight is commanded until reaching the VNAV path, then the aircraft captures the VNAV path.

Note: When a PROC HOLD is active, VNAV altitude intervention functions normally by causing the next waypoint altitude constraint to be deleted and a descent to be initiated.

When using VNAV PTH or VNAV SPD, the selection of altitude intervention will:

- delete the next climb or descent waypoint altitude constraint if the MCP altitude is beyond the next altitude constraint and
- delete approach altitude constraints if the MCP altitude is beyond the next altitude constraint.

When using VNAV ALT, selection of altitude intervention:

- may delete down path altitude constraints if the altitude constraint is within 150 feet of the current aircraft altitude and
- does not effect other altitude constraints.

Vertical Path Construction

This section describes typical final approach vertical profile (path) construction criteria as they relate to flying instrument approaches using VNAV.

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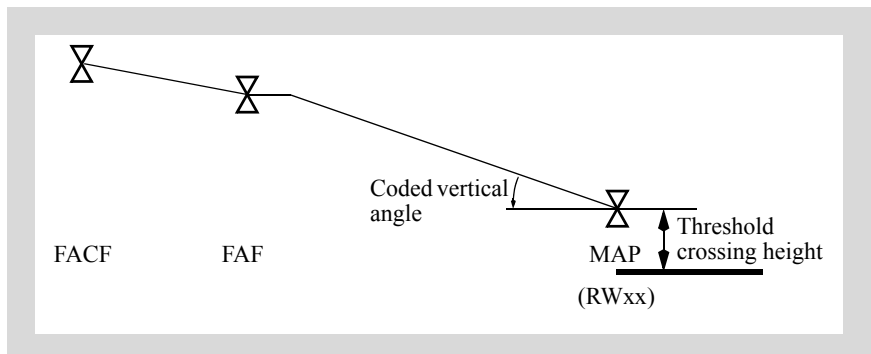
Where there is a glide path (GP) angle coded in the navigation database, the FMS builds the descent path upward and back in the direction of the FAF by starting at the location of the missed approach waypoint (MAP) and its associated altitude constraint. The FMS calculates this path using the coded GP angle, also called the vertical angle. The MAP is normally shown on the LEGS page as a RWxx or MXxx waypoint. In some cases a named waypoint is used as the MAP. A GP angle is coded in the navigation database for nearly all straight-in approach procedures.

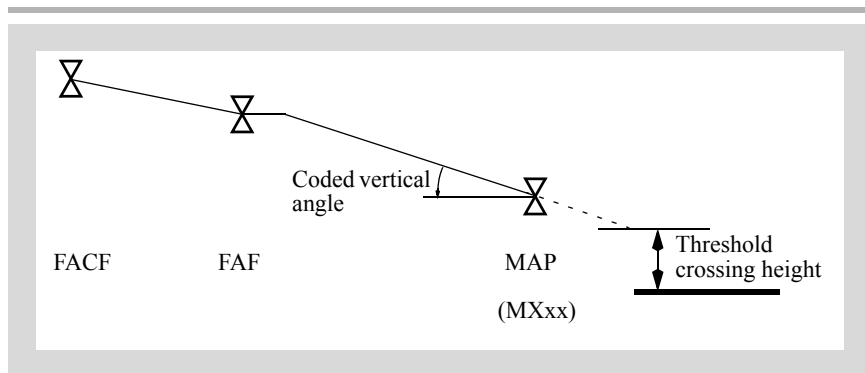
This GP angle provides a continuous descent at a constant flight path angle for a final approach path that complies with minimum altitudes at intermediate step-down fixes. The typical GP angle is approximately 3.00° , but can vary from 2.75° to 3.77° .

The projection of the vertical path upward and back toward the FAF along this coded GP angle stops at the next higher limiting altitude in the vertical profile. This limiting altitude is the more restrictive of the following:

- the “At” altitude on the constrained waypoint preceding the MAP,
- the crossing altitude on the next “at or above” constrained waypoint preceding the MAP,
- the speed transition or the speed restriction altitude, whichever is lower, or
- cruise altitude.

The following examples show typical VNAV final approach paths where there is a GP angle in the navigation database. The first example shows an RWxx missed approach waypoint. The second example below shows the VNAV final approach path where there is a missed approach waypoint before the runway. Note that in the second case the projected path crosses the runway threshold at approximately 50 feet. VNAV guidance is level flight, however, when the aircraft passes the missed approach point. Both examples are for “At” altitude constraints at the FAF.





Note: The final approach course fix (FACF) is typically located on the final approach course approximately 7 nm before the FAF. The FAF referred to in the following procedures refers to the charted FAF and is intended to mean the point at which the final approach descent is begun.

For the non-ILS approach procedures with an “At” constraint altitude at the FAF, a short, level segment between the FAF and the final glide path (also called a “fly-off”) may result. For the ILS procedure, the constraint altitude at the FAF is computed to be the crossing altitude of the glideslope.

For procedures where both the FAF and FACF are coded with “at or above” altitude constraints, the crew should consider revising the FACF altitude constraint to “at” (hard constraint). This enables a shallower path before the FAF, permitting a normal deceleration for flap and gear extension. Example: In the diagram above, if both the FACF and the FAF contain “xxx/4000A” waypoint constraints, the crew should change “4000A” to “4000” at the FACF to modify the path for a more normal deceleration.



Crews can expect to see several other variations of approach path construction:

- approaches where the FAF has an “at or above” waypoint altitude constraint. The GP angle normally terminates at the FAF altitude constraint or the cruise altitude, whichever is lower. When this type of path is flown, the aircraft passes above the FAF
- where there is more than one GP angle, such as for ILS approaches, the aircraft uses the GP angle for the active leg to define the VNAV approach path. These types of paths are shown on the LEGS page as having two GP angle values, one approaching the FAF, the second approaching the runway (missed approach point).

Note: The coded GP angle is steeper than normal in temperatures warmer than ISA standard and is shallower than normal in temperatures colder than ISA standard.

Note: ILS approaches may have step-down fixes published between the FAF and the MAP (for G/S OUT use) which are not included in the FMS database procedure. The vertical angle in the FMS database procedure may not satisfy the step-down minimum altitudes inside the FAF on these approaches.

Instrument Approach Using VNAV

Approach Preparations for Using VNAV

Select the approach procedure from the ARRIVALS page of the FMS. Tune and identify appropriate nav aids. Do not manually build the approach or add waypoints to the procedure. If additional waypoint references are desired, use the FIX page. To enable proper LNAV waypoint sequencing, select a straight-in intercept course to the FAF when being radar vectored to final approach. Verify/enter the appropriate RNP and set the DA(H) or DDA (Derived Decision Altitude (MDA(H) + 50 feet)) using the baro minimums selector. If required to use MDA(H) for the approach minimum altitude, the barometric minimums selector should be set at DDA to ensure that if a missed approach is initiated, descent below the MDA(H) does not occur during the missed approach.

Key Waypoint

The 747 VNAV approach logic operates differently than other Delta Boeing fleets. Activation of the Approach Phase does not occur with flap extension. Instead, Approach Phase activation occurs much later in the approach, when the aircraft flies over a specifically coded database approach waypoint. This is a very significant difference, as it means that the 747 begins every VNAV approach with the FMS in Descent Phase logic, and transitions to Approach Phase logic during the approach. The 747 fleet refers to the waypoint where Approach Phase begins as the Key Waypoint (KEY WPT). To provide pilot awareness of where the logic change occurs, the crew procedurally identifies the KEY WPT on the ROUTE PAGE, and enters it on the FIX PAGE, resulting in a green circle around the KEY WPT on the ND map. This step is for situational awareness only and does not effect the operation of the VNAV system in any way.

The KEY WPT is normally the first waypoint of the approach procedure when the approach is selected from the FMS database. It is commonly located prior to the FAF. Modifications to the approach course by the pilot, or as a result of ATC vectoring, can change the location of the KEY WPT, and the activation of Approach Phase, in the following ways:

- Selecting an Approach Transition or STAR. If the selected Transition or STAR connects directly to the approach at the original KEY WPT, the point where Approach Phase begins may be shifted one waypoint closer to the runway. This is because the FMS does not consider a single waypoint to be both the end of the transition, and the first point on the approach.
- Selecting an intercept line into a fix inside of the original KEY WPT. If ATC vectors the aircraft to intercept the final approach course inside of the original KEY WPT, the crew must create an intercept line into the correct TO waypoint on the approach. Approach phase will now begin when crossing that new waypoint.
- Selecting an intercept line into the runway waypoint. When on a visual approach, with only the runway waypoint on the LEGS PAGE, there is no KEY WPT and Approach Phase will begin approximately 25 miles prior to the runway.

In the first two scenarios the actual updated KEY WPT will be displayed on the ROUTE PAGE as described in Approach Considerations, after the changes are executed. In the case of a visual approach, there is no approach selected so no KEY WPT is displayed.

Because locating the KEY WPT is for situational awareness only, crews are not required to change or delete the FIX PAGE location unless desired and time permits.



Transition to an Instrument Approach Using VNAV

There are several techniques which help ensure a smooth descent transition to a non-ILS final approach where VNAV PTH will be used.

Note: The KEY WPT is normally the waypoint shown on the LEGS page and map display prior to the final approach segment. The following discussions assume the KEY WPT altitude constraint is set in the MCP while descending toward the KEY WPT. The following discussions also assume that all required criteria, mentioned in the specific approach briefing guide, this chapter, has been met prior to setting DA/DDA rounded up to the next higher 100 feet.

The 747 normally flies the transition to a non-ILS approach with VNAV engaged and the MCP SPD window opened. Prior to crossing the KEY WPT all descents will be made using Descent Phase logic. While descending, VNAV SPD will be displayed on the FMA, and the auto throttles will command IDLE, then HOLD. The aircraft will descend directly to the KEY WPT altitude and will not try to track the vertical path. Once HOLD is displayed, the pilot can vary the descent rate, to track the displayed path, by adjusting thrust as desired. When the aircraft captures the KEY WPT altitude, VNAV PATH will be displayed. If ATC requires a level off above the KEY WPT altitude, VNAV ALT will be displayed and the MCP ALT knob must be pressed when further descent is desired. Prior to the KEY WPT the aircraft will NOT transition automatically from VNAV ALT to VNAV PATH when intercepting the vertical path.

CAUTION: Prior to the KEY WPT, protections associated with Approach Phase logic are not active and the pilot must be aware of the Approach Procedure cautions regarding altitude intervention within 150 feet of the active waypoint constraint altitude. Failure to follow the procedure accurately can result in a premature, unconstrained descent below the approach segment minimum altitudes.

When cleared for the approach, the MCP altitude must be set to DA/DDA rounded up to the next highest 100 feet prior to crossing the KEY WPT. When crossing the KEY WPT, Approach Phase will become active, VNAV PATH will be displayed and the aircraft will track the vertical path to the runway. Failure to reset the MCP ALT will result in continued level flight with VNAV ALT displayed. To resume descent the pilot must set the MCP ALT to DA/DDA rounded up to the next highest 100 feet, and press the MCP ALT knob. VNAV SPD will display until the path is captured from above, then VNAV PATH will be displayed. Execute a missed approach if the deviation above path becomes excessive enough to prevent achieving a stabilized approach or if VNAV PATH is not displayed by 1,000 feet AGL.

If descending to the KEY WPT altitude in FLCH or V/S, prior to the KEY WPT verify that ALT HOLD is displayed before setting DA/DDA rounded up to the next 100 feet in the MCP. If the DA/DDA rounded up to the next 100 feet is set while FLCH or V/S is still displayed, the aircraft may descend below the FAF altitude constraint before intercepting the VNAV glide path. After DA/DDA rounded up to the next 100 feet is set, select VNAV and select speed intervention. Confirm VNAV PTH is active.

Final Approach Using VNAV

Approaching intercept heading, select flaps 5. When established on an intercept heading, ensure LNAV or other appropriate roll mode is armed or active. Prior to the KEY WPT, set the DA/DDA rounded up to the next 100 feet in the MCP altitude window, select VNAV, and ensure VNAV PTH and appropriate roll mode is annunciated. Select gear down, flaps 20, and arm the speedbrake. Use speed intervention to control speed.

When using LNAV to intercept the final approach course, shallow intercept angles or intercept angles that result in an overshoot may result in delayed capture of the final approach course. The FAF should not be crossed and descent should not begin if the aircraft is not on the final approach course.

Prior to the FAF, select landing flaps, slow to final approach speed, and do the Landing checklist. If the charted FAF is too close to the runway to permit a stabilized approach, configure for landing and establish the final approach pitch mode prior to initiating final descent.

With the MCP altitude set to DA/DDA rounded up to the next 100 feet and the aircraft stabilized on the final approach path, the map altitude range arc assists in monitoring the vertical path. Set the missed approach altitude no later than 1,000 AGL when the aircraft is at least 300 feet below the missed approach altitude and stabilized on final approach in VNAV PTH. VNAV path deviation indications on the map display assist in monitoring the vertical profile. The autopilot tracks the path in VNAV PTH until arriving at DA or DDA.

On the VNAV approach, the missed approach altitude is set after established on the final descent and more than 300 feet below the missed approach altitude. Some approaches have missed approach altitudes that are lower than the altitude at which the FAF is crossed. The flight crew must wait until the aircraft is at least 300 feet below the missed approach altitude before setting the missed approach altitude in the MCP to avoid level off from occurring during the final approach descent.

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Decision Altitude (DA)/Derived Decision Altitude (DDA)

When specifically authorized by the appropriate regulatory authority, approaches may be flown to the following minima:

- a published VNAV DA(H) and
- a published MDA(H) used as a decision altitude.

When either of the above minima are not specifically authorized, a published MDA(H) + 50 is used as a Derived Decision Altitude (DDA).

The following diagram illustrates an approach procedure containing DA(H) and MDA(H) minimums for approaches using LNAV/VNAV or LNAV only.

STRAIGHT-IN LANDING RWY 28R				CIRCLE - TO - LAND	
LNAV/VNAV DA(H) 740' (727')		LNAV MDA(H) 1000' (987')		Max Kts.	MDA(H)
ALS out		ALS out			
A	2	RVR 40 or 3/4	RVR 60 or 1 1/4	90	1000' (987') - 2
B		RVR 50 or 1	1 1/2	120	
C		2 1/2	3	140	1140' (1027') - 3
D				165	1160' (1147') - 3
	2 1/4				

Note: Some non-ILS approaches specify a VNAV DA(H).

When reaching the DA or DDA be prepared to either disengage the autopilot and land or execute an immediate go-around.

The pilot monitoring should expand the instrument scan to include outside visual cues when approaching DA or DDA. Do not continue the approach below DA or 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 DA or DDA or any time thereafter, if any of the above requirements are not met, immediately execute 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. While VNAV PTH guidance may still be used as a reference once the aircraft is below DA or DDA, the primary means of approach guidance is visual.

Note: On some approaches where the runway is not the end of descent point (E/D), VNAV path guidance transitions to level flight once the missed approach fix is passed.

Simulated Instrument Approach Using VNAV

To maintain proficiency, crews may practice instrument approach using VNAV procedures while flying ILS approaches as follows:

- Ensure the ILS is tuned and identified and the ILS raw data is monitored throughout the approach.
- Track the localizer using LOC or LNAV as the roll mode.
- Use VNAV as the pitch mode to track the GP angle. The GP angle on the approach chart normally coincides with the ILS glideslope angle.
- Disengage the autopilot by the minimum altitude specified in the Limitations chapter of the Vol. 1.

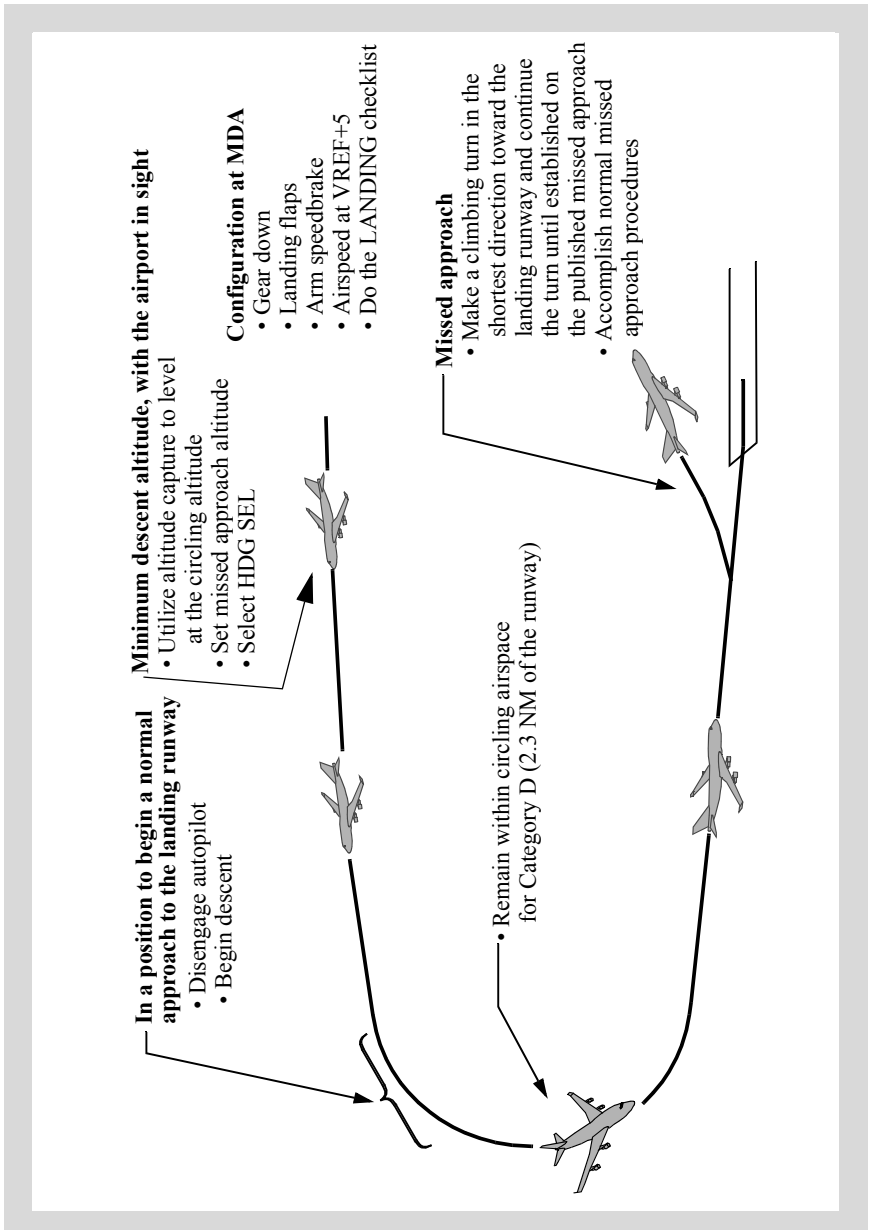
Note: Limit the use of the above technique to VMC weather conditions.

In ambient temperature conditions warmer than ISA standard, the aircraft may remain slightly high relative to the ILS glideslope, and in temperatures colder than ISA standard, the aircraft may remain slightly lower than the ILS glideslope. Discontinue use of this technique and manually track the localizer and glideslope if localizer or glideslope deviations become unacceptable.

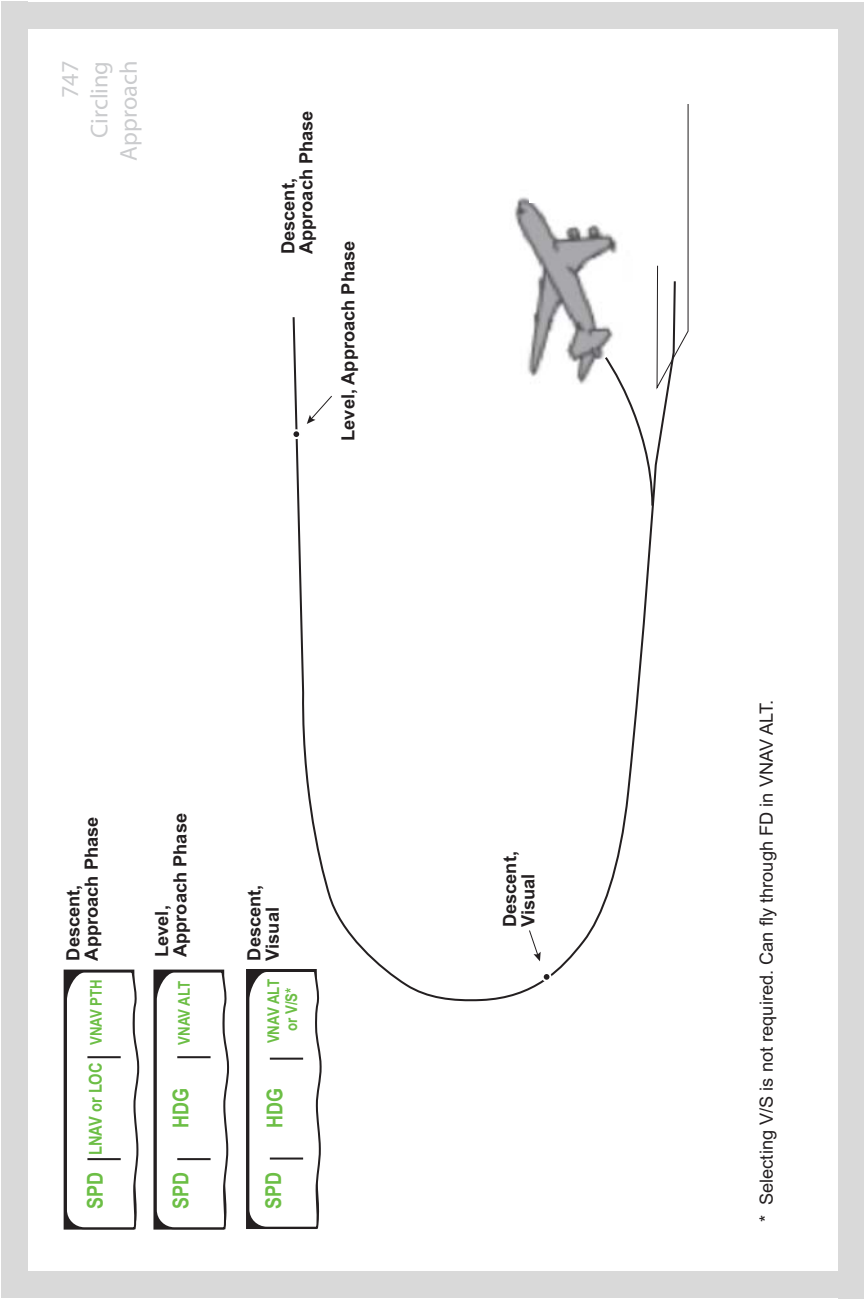
Circling Maneuver

A circling approach may be flown following an instrument approach using VNAV provided the MCP altitude is set in accordance with the circling approach procedure.

Circling Maneuver Profile



FMA Progression



Approach Guide

Refer to Vol. 1, NOI.3 for Circling Maneuver guidance.

Circling Maneuver - General

The following guidance supplements normal approach preparations and procedures for the type of approach to be flown.

To minimize challenges of flying cross-cockpit, consider the direction of the circling maneuver when assigning PF duties.

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 VNAV mode to descend to the circling MDA. Use of the APP Mode for descent to the circling MDA is not recommended for several reasons:

- the AFDS does not level off at MCP altitude
- exiting the APP Mode requires initiating a go-around or disengaging the autopilot and turning off the flight directors.

Maintain MDA using ALT or VNAV ALT mode. 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.

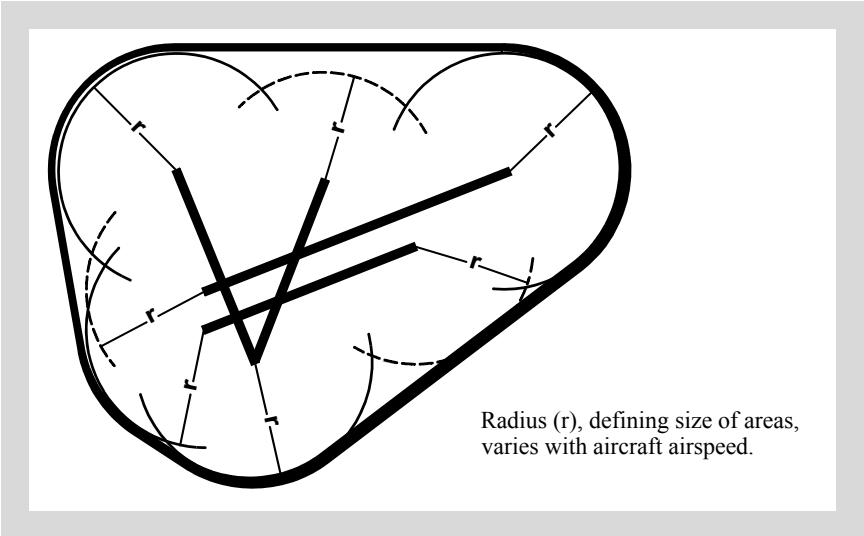
When in ALT or VNAV ALT at MCP altitude or the MDA and before commencing the circling maneuver, set the missed approach altitude.

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.



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

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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  in the minima block of the Jeppesen chart.

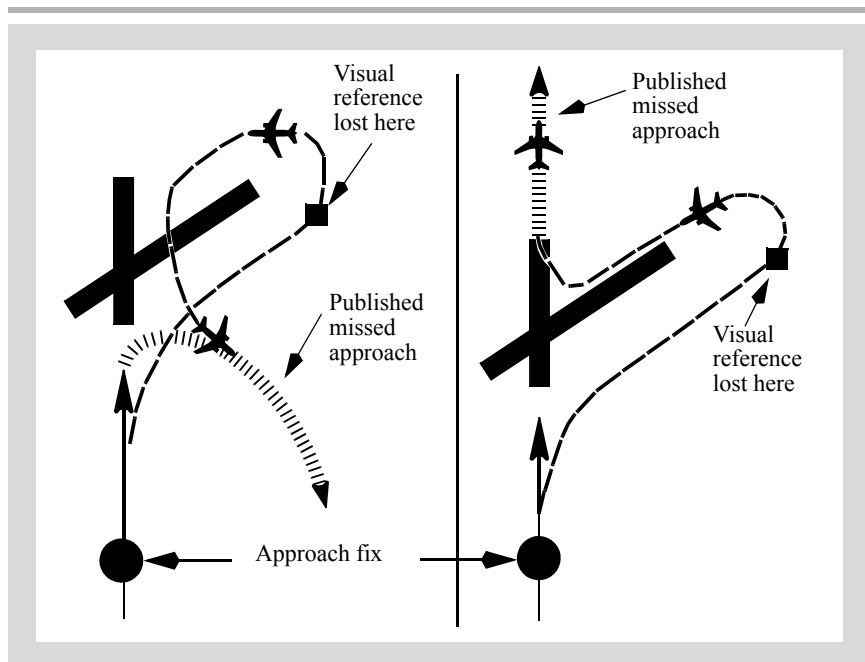
Note: Adjust aircraft heading so the aircraft ground track does not exceed the obstruction clearance distance from the runway at any time during the circling maneuver.

Note: Aircraft maneuvering outside of the circling airspace do not have guaranteed obstacle clearance protection.

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.



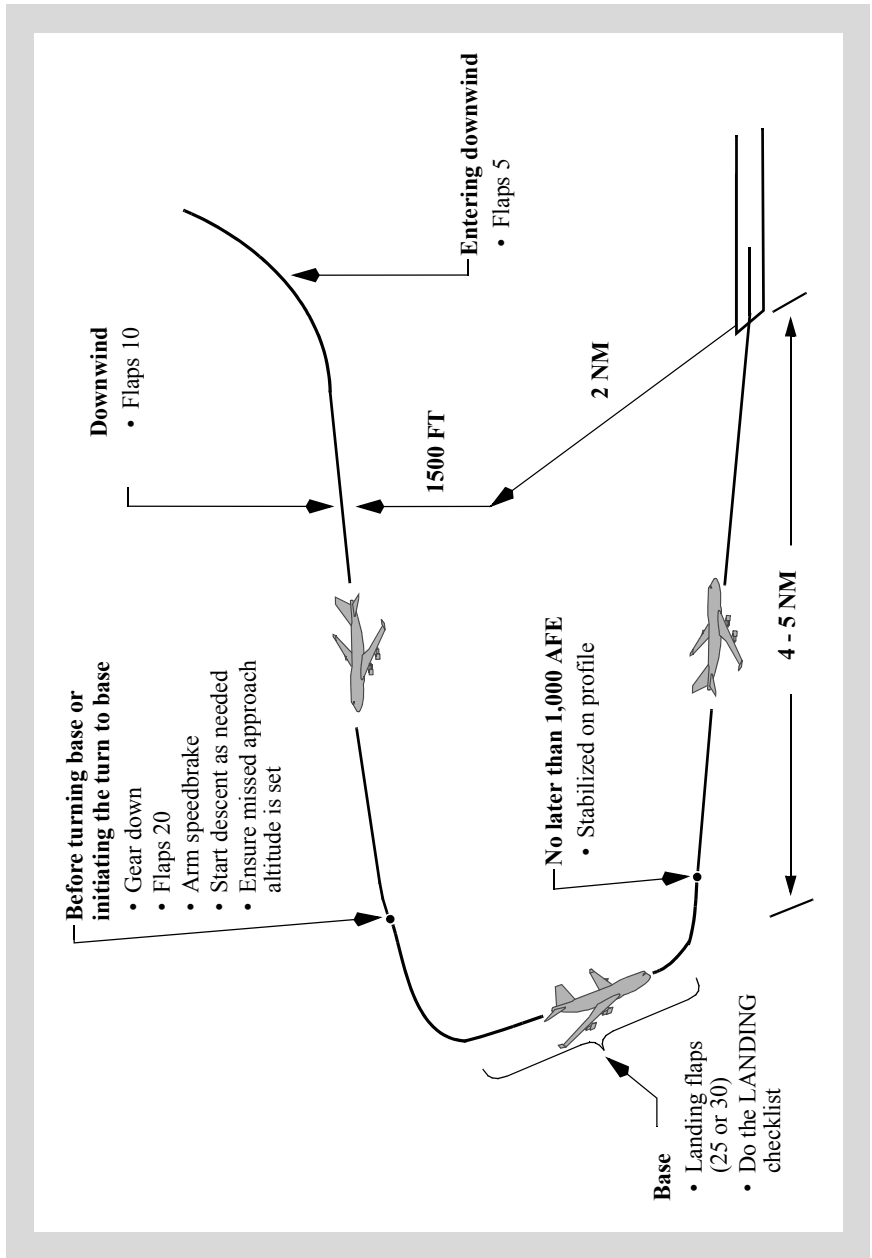
In the event that a missed approach must be accomplished from below the MDA, consideration should be given to selecting a flight path which ensures safe obstacle clearance until reaching an appropriate altitude on the specified missed approach path.

Note: If a go-around is selected with either flight director switch in the OFF position, the flight director pitch or roll command bar on the corresponding side will appear when the first pitch or roll mode is selected or engaged.

Refer to Go-Around and Missed Approach - All Approaches, this chapter.

Visual Approach

Visual Approach Profile



Visual Approach - General

The recommended landing approach path is approximately $2\frac{1}{2}^\circ$ to 3° . Once the final approach is established, the aircraft 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

Fly at an altitude of 1,500 feet above the runway elevation and enter downwind with flaps 10 at flaps 10 maneuver speed. Maintain a track parallel to the landing runway approximately 2 nm abeam.

Before turning base or initiating the turn to base, extend the landing gear, select flaps 20, arm the speedbrake, and slow to flaps 20 maneuver speed or approach speed plus wind additive if landing at flaps 20. If the approach pattern must be extended, delay lowering gear and selecting flaps 20 until approaching the normal visual approach profile. Turning base leg, adjust thrust as required while descending at approximately 600-700 fpm.

Extend landing flaps before turning final. Allow the speed to decrease to the proper final approach speed and trim the aircraft. Do the Landing checklist. When established in the landing configuration, maneuvering to final approach may be accomplished at final approach speed (VREF plus wind additive).

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. Use of the autothrottle is recommended. However, if controlling thrust manually, attempt to keep thrust changes small to avoid large trim changes. 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.

Note: Descent rates greater than 1,000 fpm should be avoided. However, there are conditions during heavyweight approaches and/or when using three bar VASIs where momentary excursions slightly above 1,000 fpm may apply.



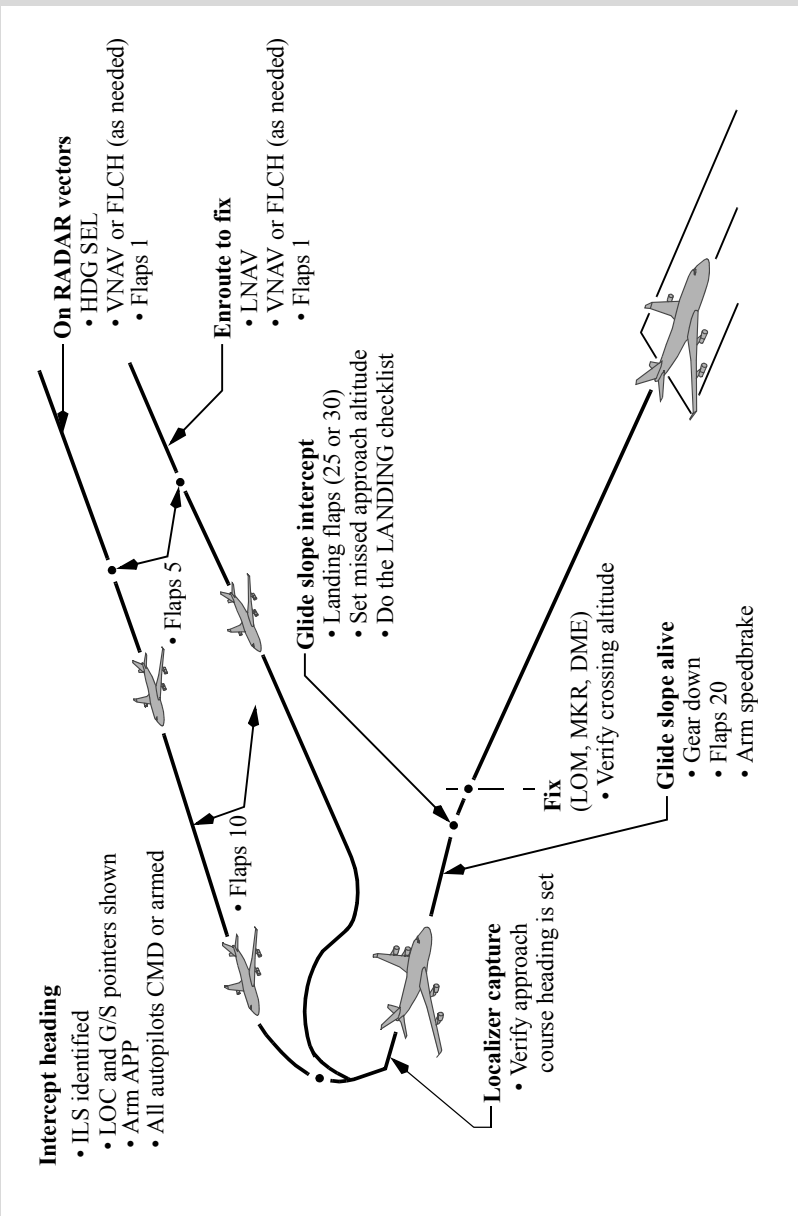
Internal Visual Cues

Select an approach from the FMS that has the runway end (RWXX) as a waypoint on the procedure. In the absence of an approach to the runway, select the runway. Input the TDZE + 50 feet for the RWXX waypoint (e.g., TDZE 1,026 feet + 50 feet = RW09R xxx/1,080 feet). If TDZE + 50 feet = less than 1,000 feet, it must be entered as 4 digits. For example, 180 feet is entered as /0180. Make the runway the active waypoint and set the intercept course to the inbound course. Use the cross track indication to establish the desired downwind leg displacement. Use the VNAV path pointer to reference the vertical path to the runway. Reference the RWY symbol on the ND (10 mile scale) for the turn to base leg. Just prior to the RWY symbol disappearing from the bottom of the ND, begin configuring and initiate the base turn. Initiate the turn to final just prior to the Position Trend Vector touching the runway extended centerline (magenta line).

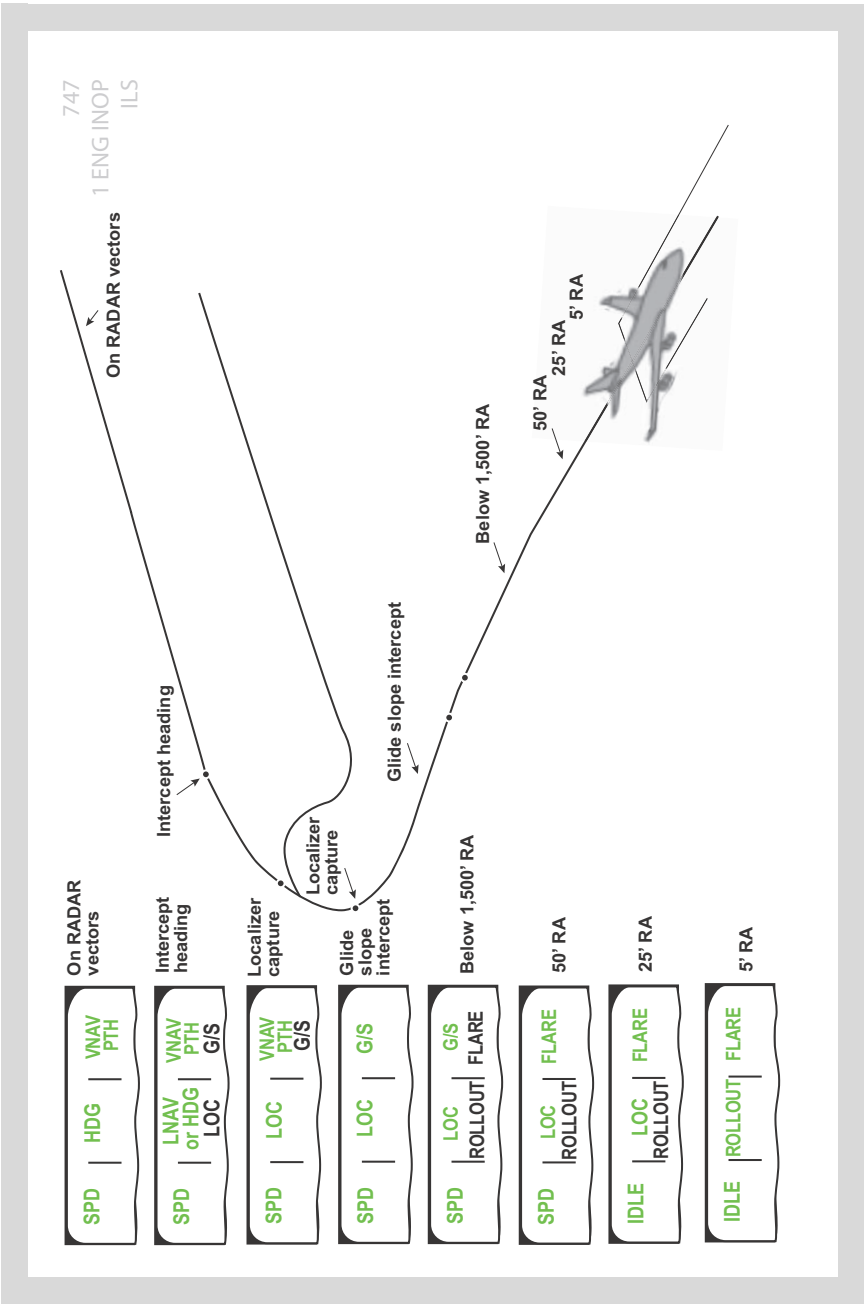
Engine Inoperative Approach Operations

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.

ILS Approach Profile - One Engine Inoperative



FMA Progression



ILS Approach - One Engine Inoperative

AFDS management and associated procedures are the same as for the normal ILS approach.

Weather minima for an ILS with one engine inoperative are specified in Vol. 1 or the Airway Manual, Ops Specs, IAP. Flight director (manual) or autopilot and/or autothrottle may be used. Minimize thrust lever movements to reduce both asymmetry and speed changes. Airplane configuration changes require little thrust change until capturing the glideslope.

Intercept the localizer with flaps 5 at flaps 5 speed. As an option, the localizer may be intercepted at flaps 10 and flaps 10 speed. This helps prevent a localizer overshoot when using large intercept angles by providing a smaller turn radius. When the glideslope is alive, lower the landing gear and extend flaps to 20. At glideslope capture, select landing flaps, set final approach speed, and decelerate. For a discussion about how yaw is controlled during an approach with one engine inoperative, refer to the section titled Engine Inoperative, Rudder Trim - All Instrument Approaches later in this chapter.

Be prepared to take over manually in the event system performance is not satisfactory.

If flown to an autoland, additional engine-out logic is incorporated during runway alignment to ensure the downwind wing is not low at touchdown. If the crosswind is from the same side as the failed engine, then the airplane is crabbed by inducing a sideslip. This assures a “wings-level” approach. For moderate or strong crosswinds from the opposite side of the failed engine, no sideslip is induced as the failed engine high approach configuration guarantees an upwind wing low touchdown characteristic.



Engine Inoperative, Rudder Trim - All Instrument Approaches

During an ILS, multiple autopilot approach, the pilot must use rudder pedal pressure to control yaw, followed by rudder trim to maintain an in-trim condition until LAND 3 or LAND 2 annunciates. When LAND 3 or LAND 2 annunciates, rudder inputs are controlled by the autopilots. Directional control (yaw) is not affected by rudder trim with the autopilot in the LOC or ROLLOUT modes. Manually centering the rudder trim prior to thrust reduction for landing is normally unnecessary.

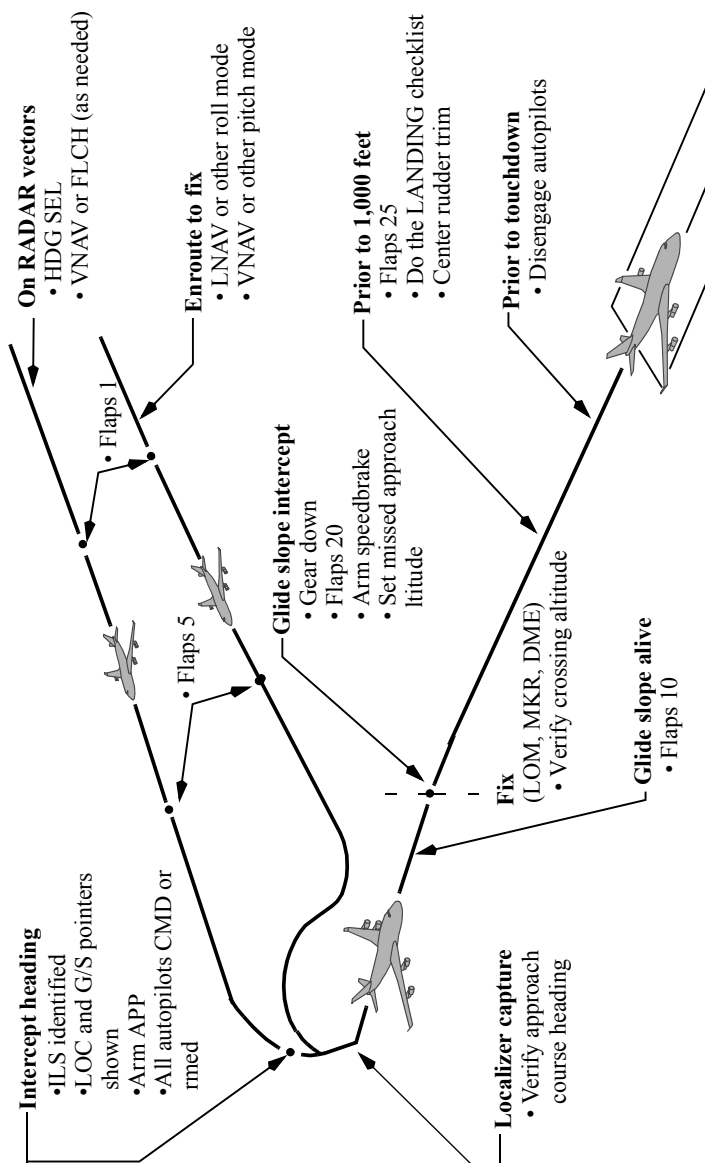
If the pilot desires to center the rudder trim, it should be accomplished prior to 1,000 feet AFE to allow the PM ample time to perform other duties and make appropriate altitude callouts.

Centering the rudder trim before landing allows most of the rudder pedal pressure to be removed when the thrust of the operating engine(s) is retarded to idle at touchdown. Full rudder authority and rudder pedal steering capability are not affected by rudder trim.

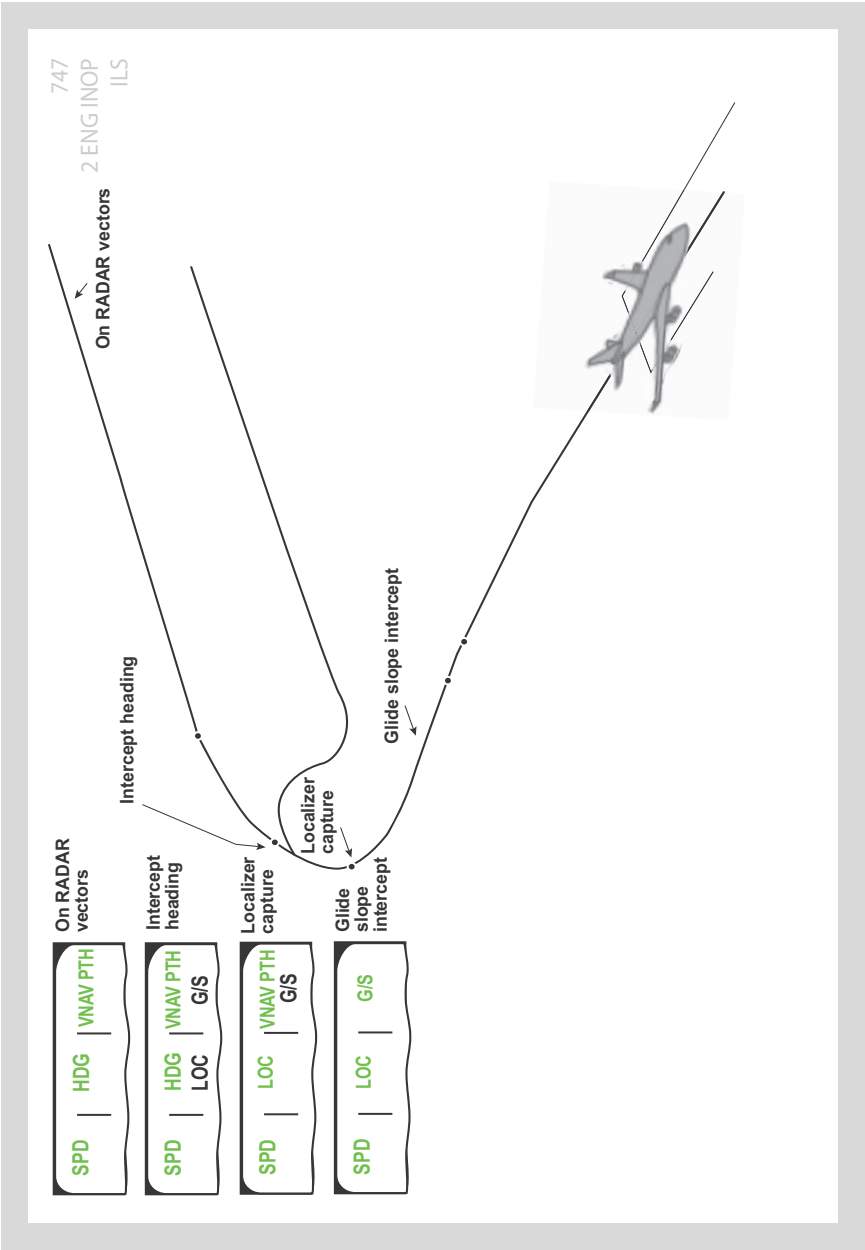
It may not be advisable to center the rudder trim due to crew workload and the possibility of a missed approach. However, if touchdown occurs with the rudder still trimmed for the approach, be prepared for the higher rudder pedal forces required to track the centerline on rollout.

During a single autopilot (non-ILS) or flight director (manual) approach, the pilot must use rudder pedal pressure to control yaw, followed by rudder trim to maintain an in-trim condition. During a single autopilot approach, the pilot must control yaw during the entire approach. When accomplishing a single autopilot approach, disengage the autopilot prior to flare.

ILS Approach Profile - Two Engines Inoperative



FMA Progression



ILS Approach - Two Engine Inoperative

During all weather conditions, if a two engine inoperative approach is required, fly an approach similar to the ILS Approach - Two Engines Inoperative profile.

Do not hurry the approach. Plan the approach so sufficient time is available to systematically complete the approach procedure. Use of autopilot is permitted to reduce pilot workload but rudder trim must be controlled by the pilot, and autopilot performance monitored. If rudder trim is not controlled during thrust changes, the autopilot may not be able to maintain the selected heading. With two engines inoperative, the autothrottle automatically disconnects and cannot be reconnected.

Airspeed control is critical throughout the approach. For maximum performance margins, maintain the recommended profile speeds and do not allow speeds to decrease below flap maneuver speeds.

Commit point is gear extension. Obtain landing clearance before extending the landing gear. Extend the landing gear and select flaps 20 when intercepting the glideslope.

Note: A go-around after landing gear extension should not be attempted.

However, if a go-around is absolutely necessary, follow the procedures and techniques described in the Go-Around and Missed Approach section for two engines inoperative found at the end of this chapter.

Approaching 1,000 feet AGL, center the rudder trim and select flaps 25. Maintain a minimum of VREF 25 + 5 or the correct wind additive. A slight increase in thrust may be needed as the drag increases from flaps 20 to flaps 25. Stabilize the approach at 1,000 feet AGL and continue with a stabilized approach to touchdown. Attempt to minimize thrust lever movement. This helps reduce the yaw and pitch changes due to the thrust asymmetry, especially if the two inoperative engines are on the same side of the airplane.

With high gross weights, temperatures, and pressure altitudes, any significant deviation below the glide path must be avoided. Go-around thrust on two engines may not be sufficient to capture the glide path from below in the landing configuration.

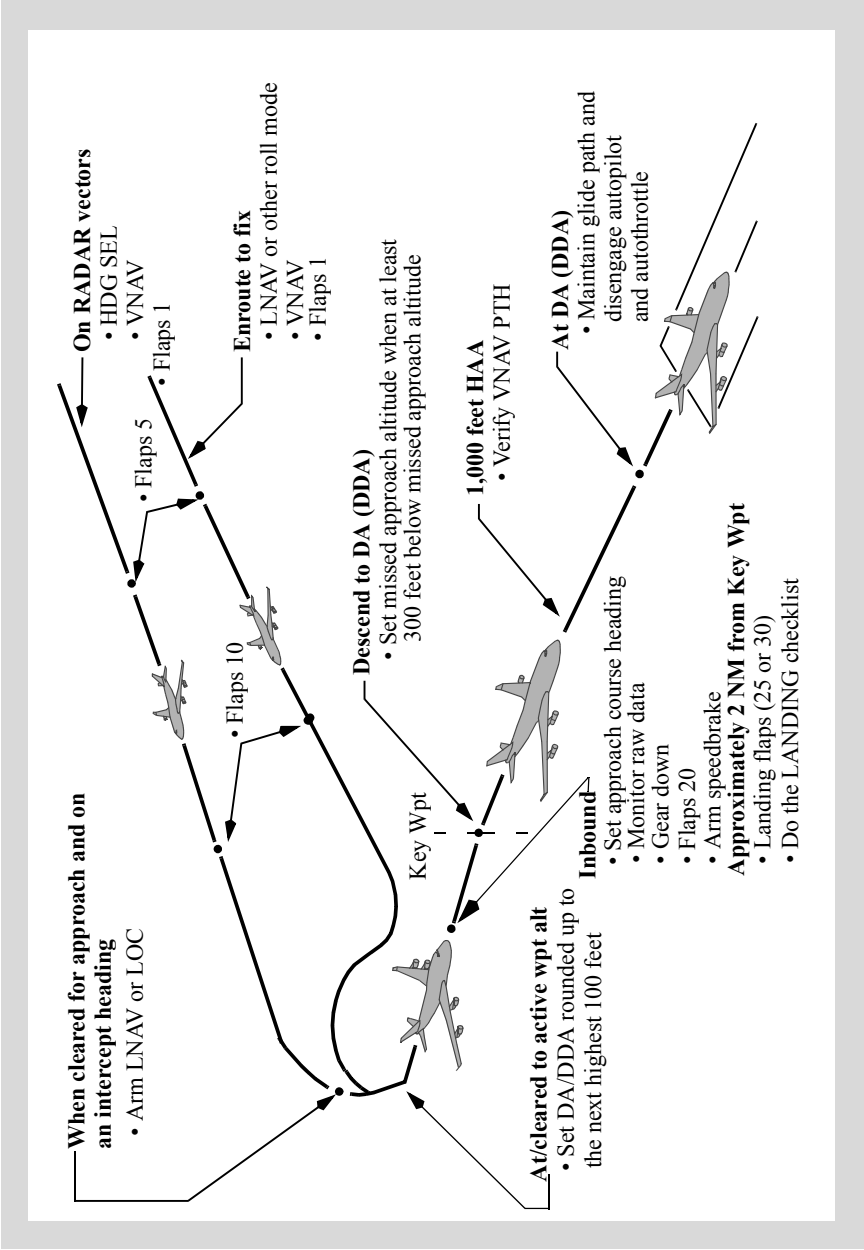


Two Engines Inoperative, Rudder Trim - All Instrument Approaches

If using a single autopilot or the flight director during the approach, use rudder pressure, followed by rudder trim to maintain a zero yaw condition (neutral control wheel). The pilot must control yaw during the entire approach.

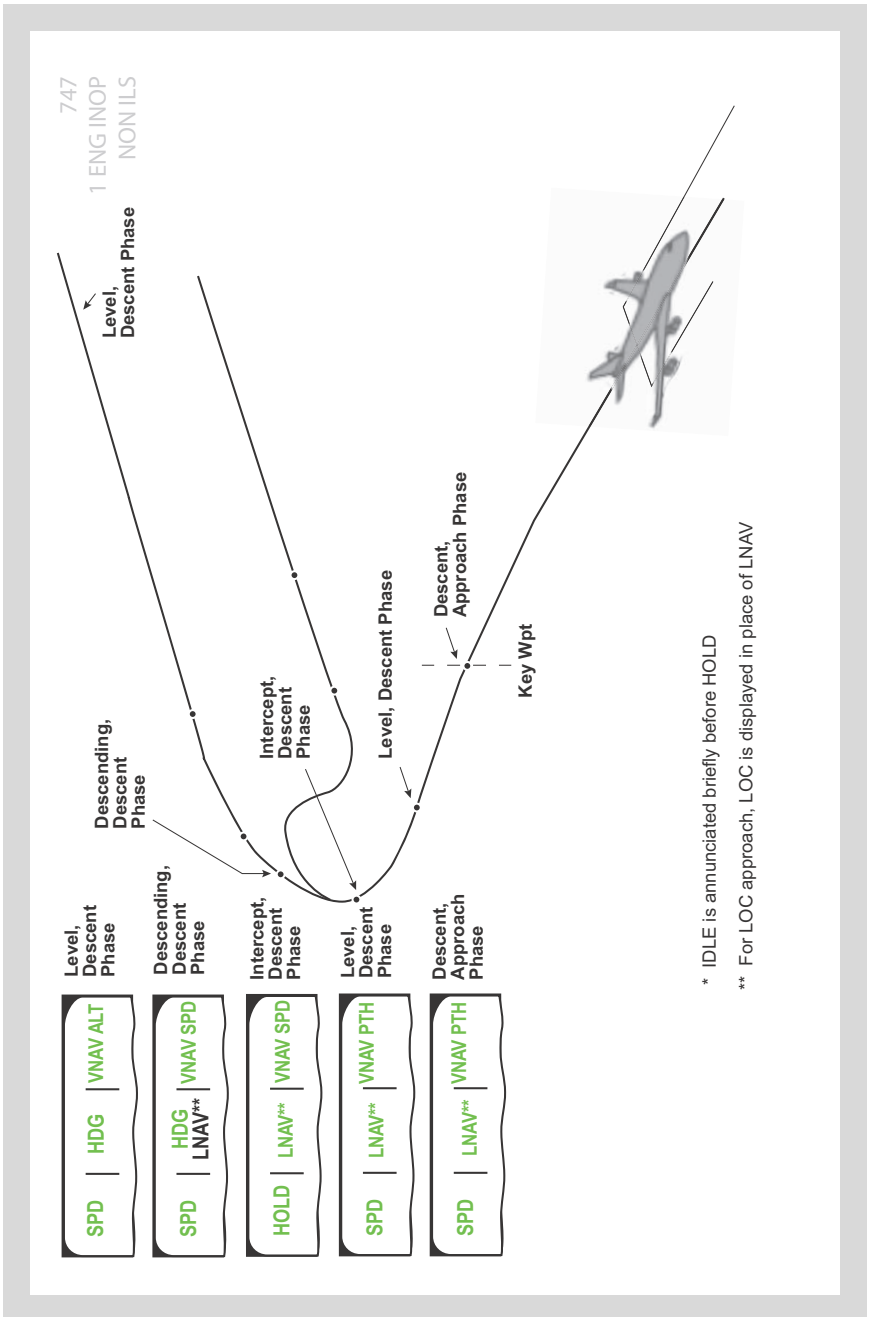
The airplane has not been demonstrated to be able to autoland with two engines inoperative. During a multiple autopilot approach, the AFDS controls the rudder to compensate for engine-out asymmetric thrust. When the autopilots are disengaged, the rudder moves to the trimmed position. During an approach with two engines inoperative on the same side, large amounts of rudder trim may have been applied before multiple autopilot engagement. To minimize the effects of rudder trim during thrust reduction in the flare and during the rollout, center the rudder trim at approximately 1,000 feet AGL. The pilot must be prepared to maintain the proper amount of rudder when the autopilots are disengaged because the airplane is not trimmed for the asymmetrical thrust condition. Consider disengaging the autopilots at a higher than normal altitude to provide time to correct the flight path before touchdown.

Non-ILS Instrument Approach Profile - One Engine Inoperative



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FMA Progression



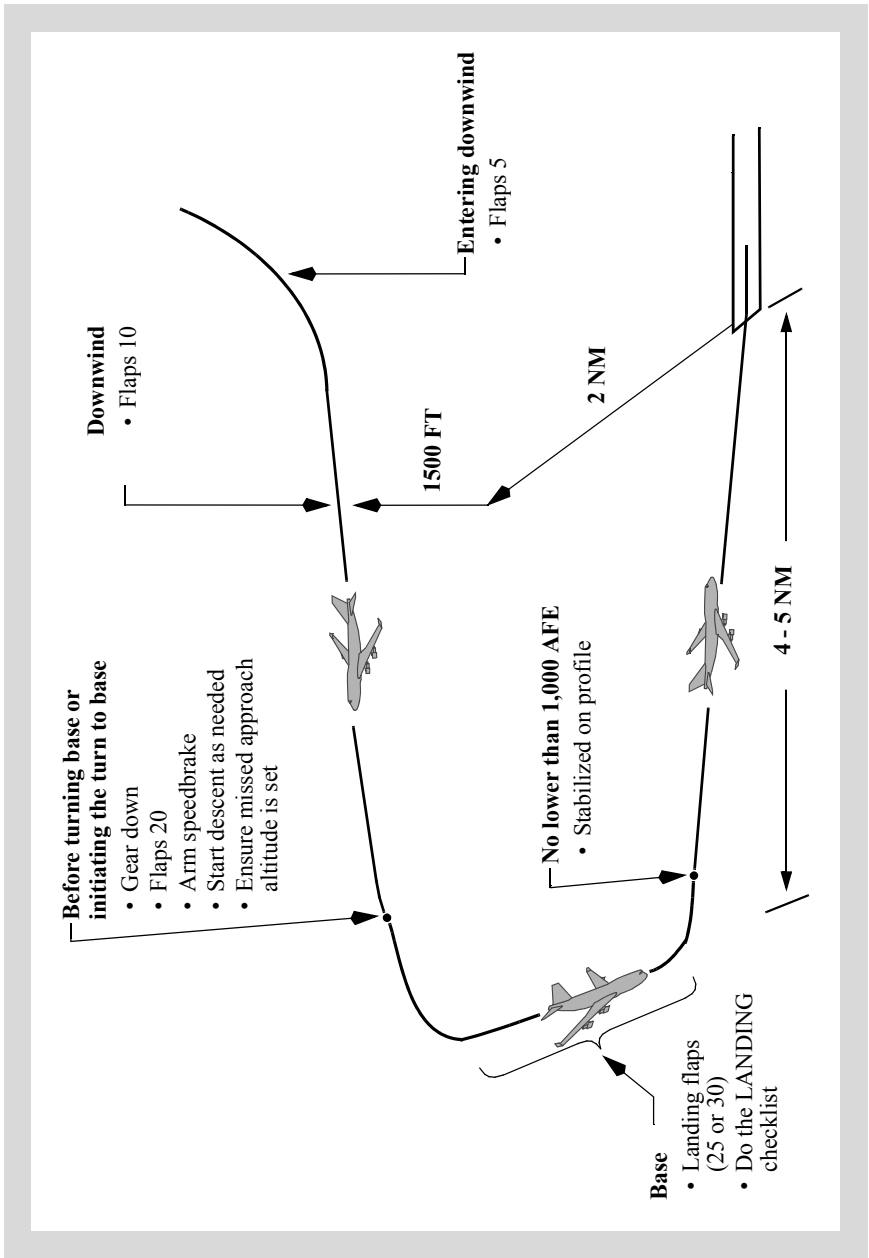
Non - ILS Approach - One Engine Inoperative

Maneuvering before and after the final approach fix with one engine inoperative is the same as for an all engine non-ILS approach.

Circling Maneuver - One Engine Inoperative

If a circling approach is anticipated, use the same procedures as used with all engines operating.

Visual Traffic Pattern Profile - One Engine Inoperative

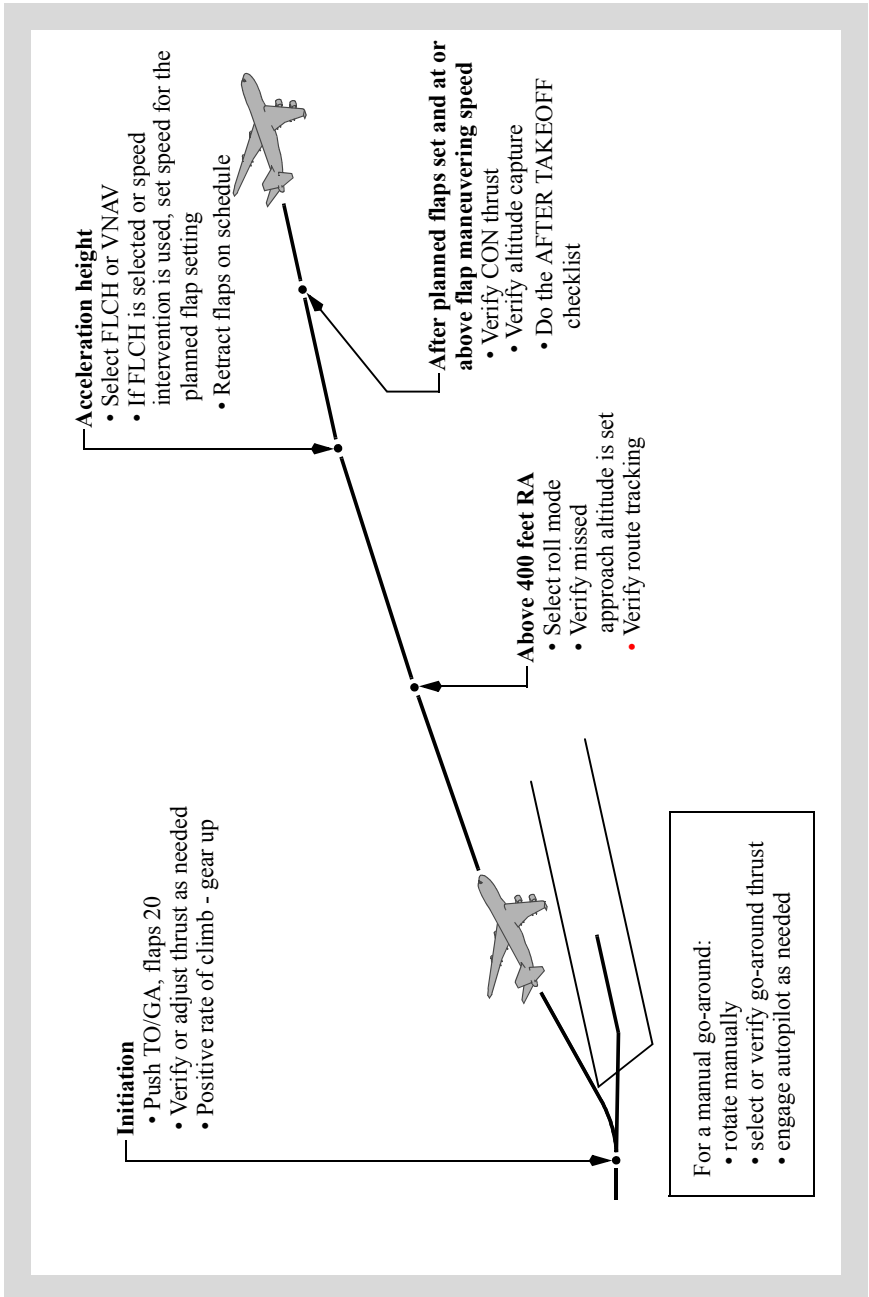


Engine Failure On Final Approach

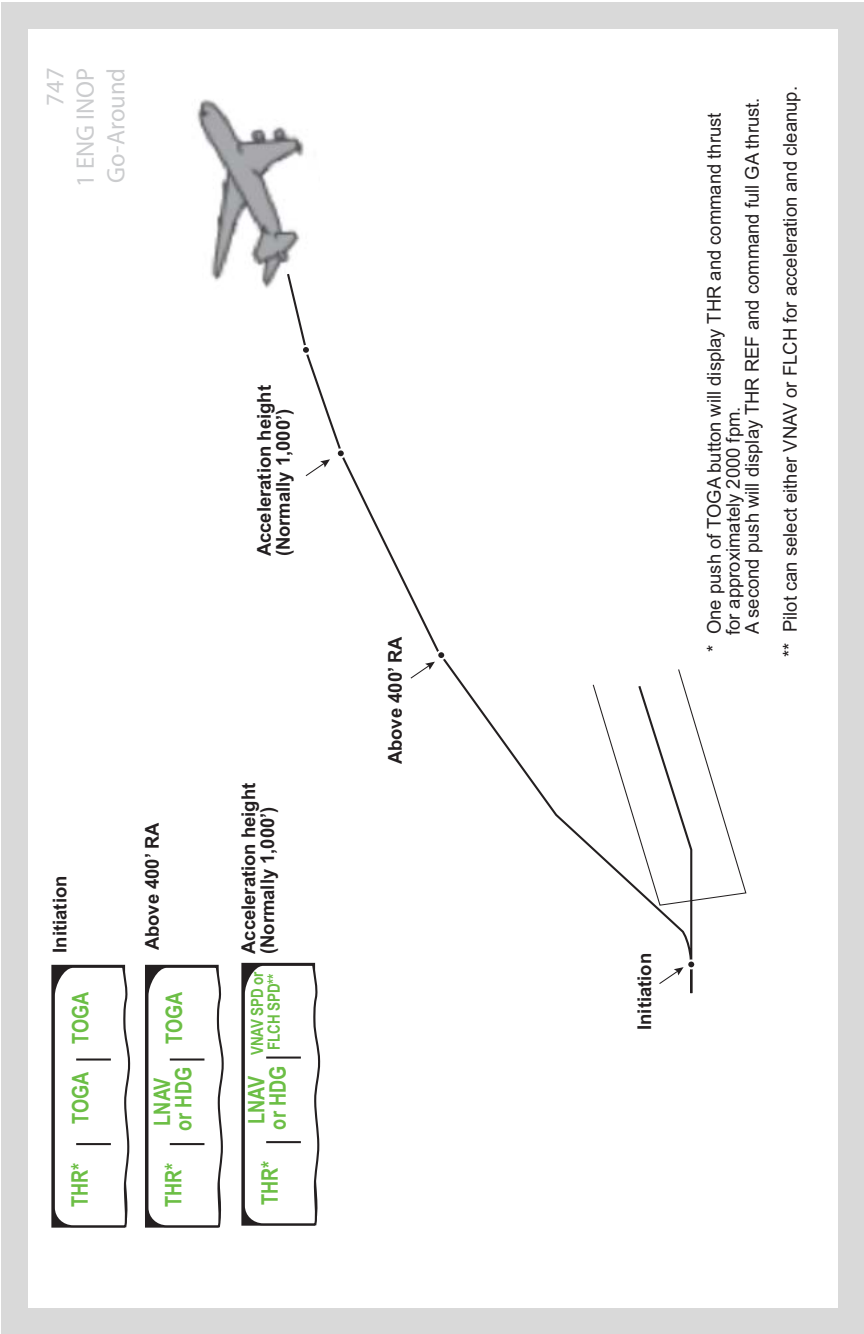
If an engine failure should occur on final approach, use normal procedures. See the ILS Approach - One Engine Inoperative section in this chapter.



Go-Around and Missed Approach Profile - One Engine Inoperative



FMA Progression



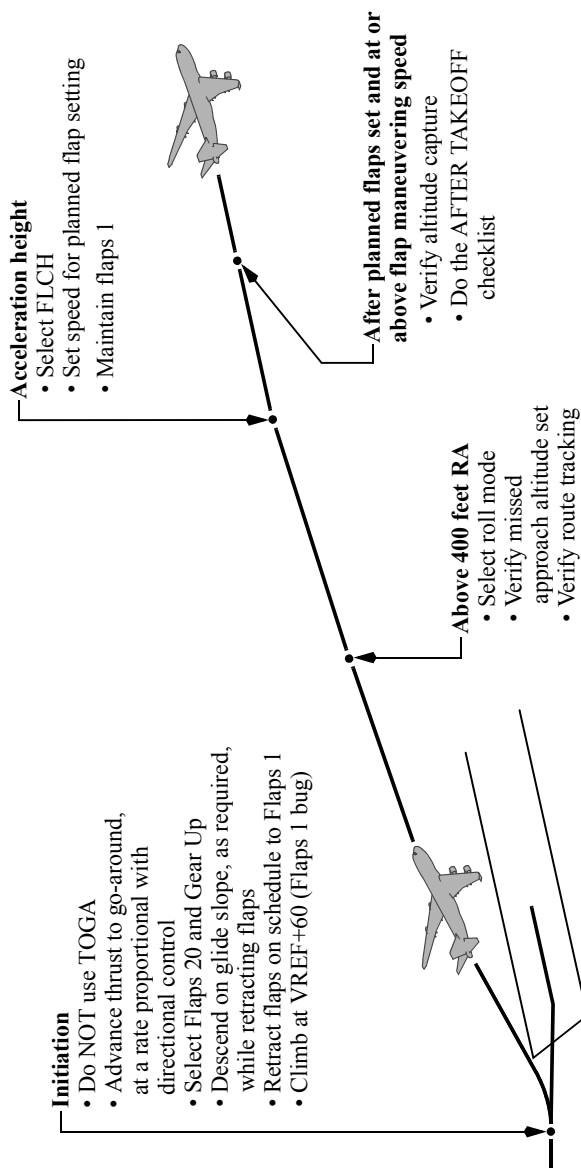


Go-Around and Missed Approach - One Engine Inoperative

The missed approach with an engine inoperative should be accomplished in the same manner as a normal missed approach. After TO/GA is engaged, the AFDS commands a speed that is normally between command speed and command speed + 10 knots. If accomplishing a manual go-around, the pilot must control yaw with rudder and trim. Some rudder pedal pressure may be required even with full rudder trim.

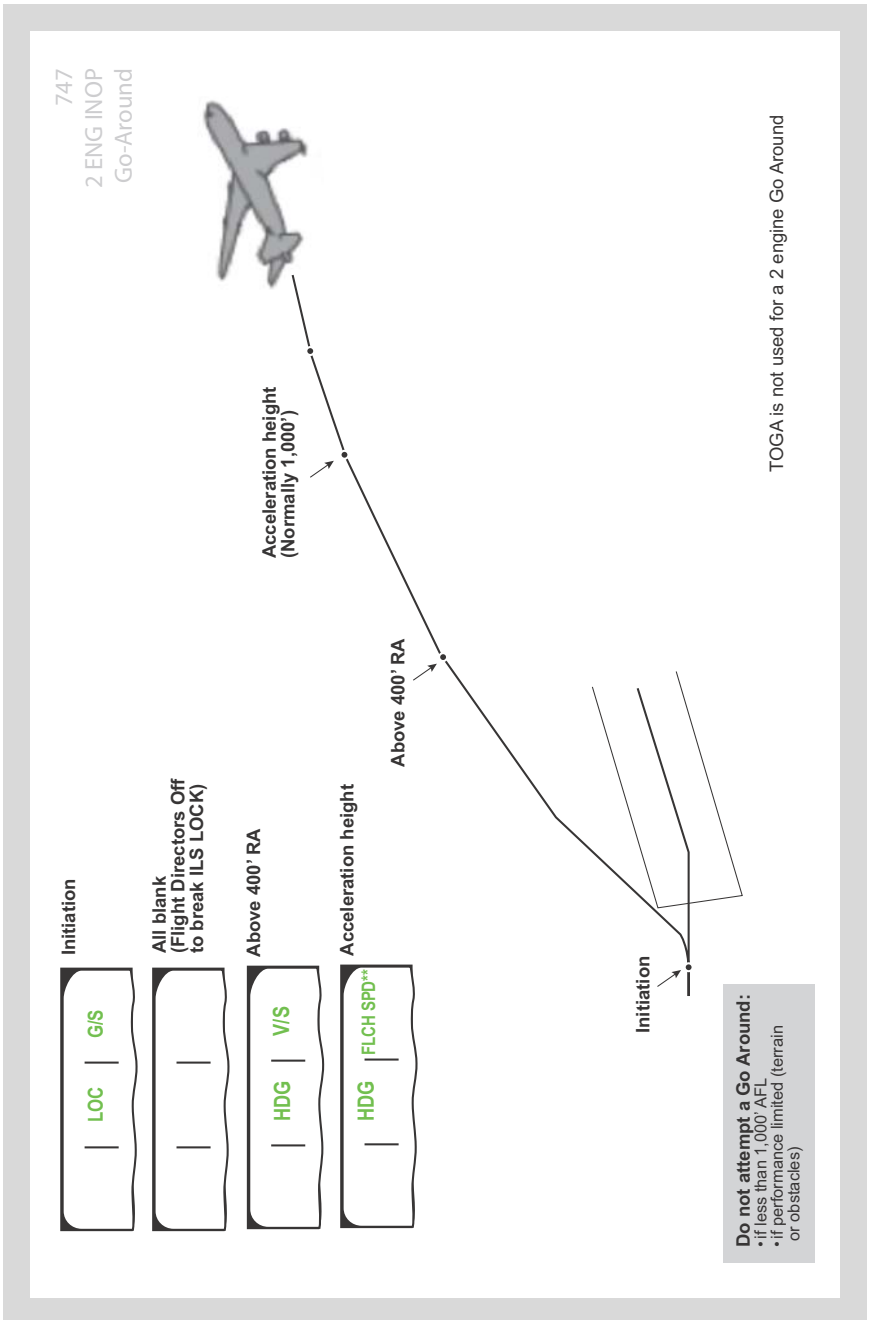
For a multi-autopilot go-around, yaw is initially controlled by the autopilots. Be prepared to immediately apply rudder input when selecting another roll mode, pitch mode, or when altitude capture occurs above 400 feet AGL because the autopilot reverts to single autopilot operation. The system reverts to normal autopilot operation and automatic control of rudder is discontinued.

Go-Around and Missed Approach Profile - Two Engine Inoperative



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FMA Progression



Go-Around and Missed Approach - Two Engine Inoperative

If a go-around is absolutely necessary, increase thrust to go-around thrust at a rate that does not exceed the rudder's capability to maintain directional control. The pilot must control yaw with rudder and trim. Some rudder pedal pressure may be required even with full rudder trim. Descend if needed to increase speed and retract flaps to flaps 1 on schedule.

Note: The use of TO/GA is not recommended. TO/GA pitch commands may exceed the performance capability of the airplane with two engines inoperative.

With high gross weights, temperatures, and pressure altitudes, go-around thrust on two engines may not be sufficient to achieve a positive gradient with flaps 20 and the landing gear extended. The landing gear may be retracted at flaps 20, or any intermediate flap setting through flaps 1.

During an approach with two engines inoperative on the same side, it is possible to be at an airspeed below minimum control speed when the go-around is initiated. Thrust should be applied with rudder application and a slight bank into the operating engines while establishing a descent for faster acceleration. As airspeed increases and the rudder becomes more effective, advance the thrust lever for the operable outboard engine to go-around thrust.

During acceleration with two engines inoperative on one side, with flaps retracted and airspeed above aileron lockout speed, the autopilot may not have sufficient aileron authority to maintain desired bank. If this occurs, the airplane must be manually flown.

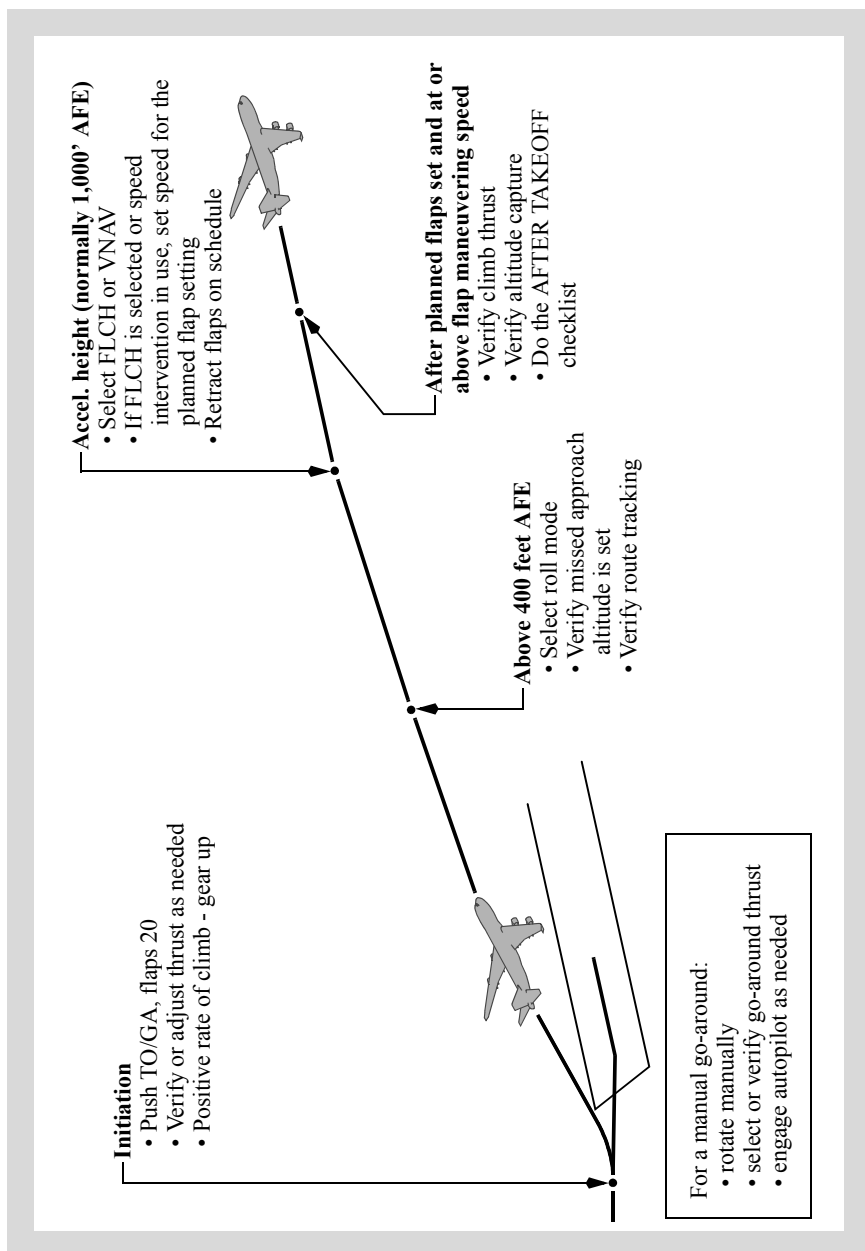
Engine Failure During Go-Around and Missed Approach

If an engine fails during a go-around the situation should be treated as though it occurred during a flaps 20 takeoff. All procedures are the same as an engine failure on takeoff.

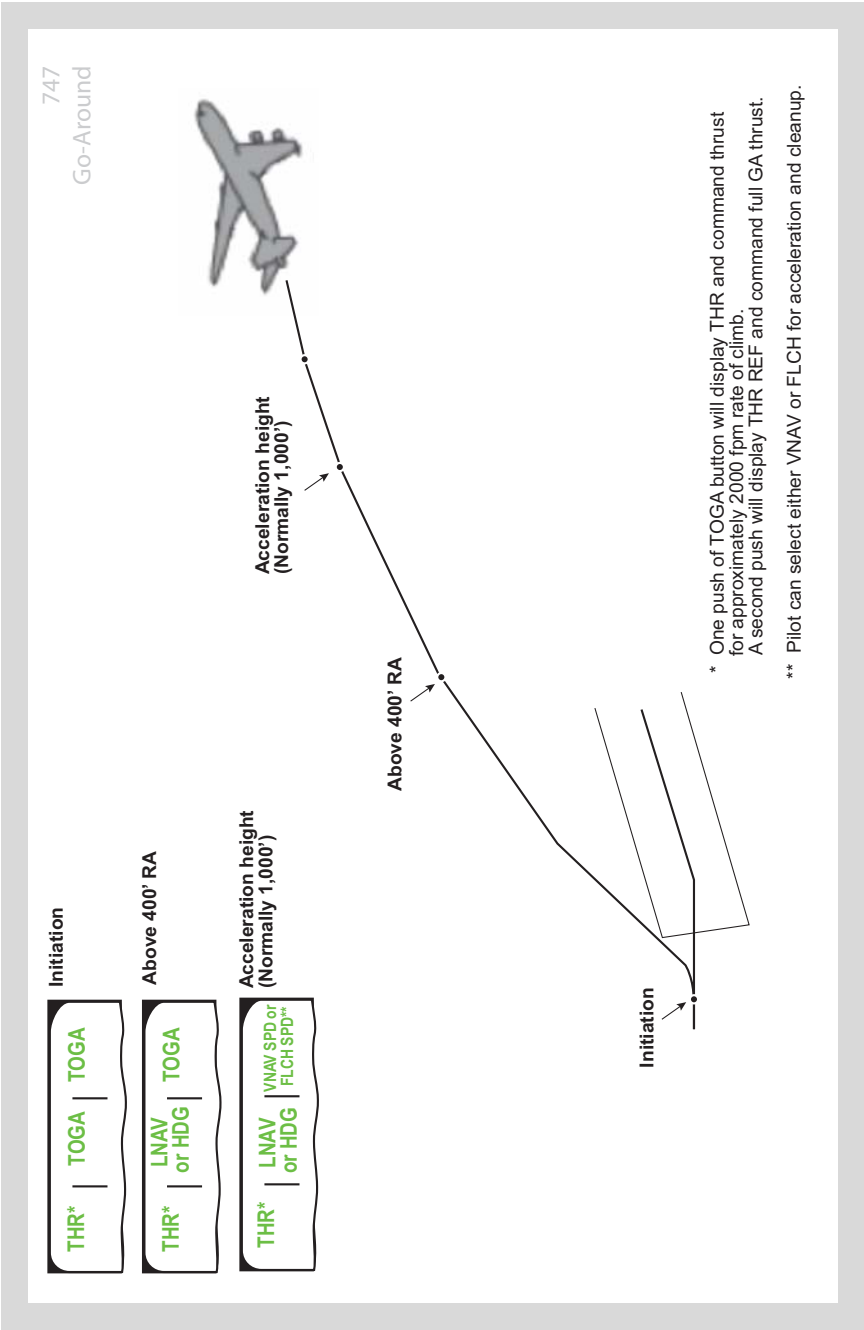


Go-Around and Missed Approach - All Approaches

Go-Around and Missed Approach Profile - All Approaches



FMA Progression





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 missed approach is required following an autopilot approach, leave the autopilots engaged. The pilot flying will push either TOGA switch and verbalize "GO AROUND". The pilot monitoring will verify that the active FMA pitch, roll, and autothrottle annunciations are THR (THR REF)/TOGA/TOGA. The level of automation should be command (CMD). After FMA verification, the pilot monitoring will verbalize the active FMA pitch mode and state "TOGA VERIFIED" or call out any FMA omissions.

Examples of FMA omissions are:

- TOGA is not annunciated - Callout - "TOGA NOT VERIFIED, PUSH THE TOGA SWITCH"
- CMD is not annunciated and the level of automation is flight director (FD) - Callout - "TOGA VERIFIED, AUTOPILOT IS OFF"
- GS and LOC are annunciated - Callout - "TOGA NOT VERIFIED, PUSH THE TOGA SWITCH"
- AT THR (THR REF) is not annunciated - Callout - "TOGA VERIFIED, NO AUTOTHROTTLES"

Any FMA mode not annunciated in TOGA, or CMD should be verbalized by the pilot monitoring.

The pilot flying calls for flaps 20, ensure go-around thrust for the nominal climb rate is set and monitor autopilot performance. Retract the landing gear after a positive rate of climb is indicated on the altimeter.

Go-Around Maneuver - All Engines Operating

Pilot Flying	Pilot Monitoring
When a go-around is initiated:	
Push either TOGA switch and announce “GO AROUND” - For a manual go-around: - rotate manually; follow the flight director - engage autopilot as needed - Assure go-around thrust**	- Verify FMA pitch, roll, and ATs are GA and announce pitch mode “TOGA VERIFIED” - Verbalize FMA annunciations other than TOGA and callout any omissions - Assure go-around thrust**
Call “FLAPS 20.”	Set FLAP lever as directed
Verify: - Rotation to go-around pitch attitude - Thrust setting - Proper FMA mode annunciation	
Verify thrust is sufficient for the go-around or adjust as needed.	
	Monitor rotation, pitch 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 landing gear lever to UP
	Verify missed approach altitude is set
	Call out any trend toward terrain contact, descending flight path, or significant airspeed changes.
Above 400 feet RA:	
Verify or call for appropriate roll mode (LNAV or HDG) and verify FMA change***	Select roll mode and verify active FMA change***



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Pilot Flying	Pilot Monitoring
If another approach is warranted at the destination airport:	
Consider leaving flaps at 5 and maintain the appropriate maneuvering speed. ****	Verify flaps 5 and appropriate maneuvering speed as directed. ****
At acceleration height (normally 1,000 feet AFE):	
Call for "FLCH" or "VNAV" as desired.	Select "FLCH" or "VNAV" as directed.
Call "FLAPS ____" according to flap retraction schedule.	Set FLAP lever as directed.
When at planned flap configuration:	
Call "AFTER TAKEOFF CHECKLIST."	Accomplish After Takeoff checklist.

Note: **One push of the TOGA switch will command the autothrottles to set 2,000 fpm climb. If a higher rate of climb is desired, push TOGA switch a second time to get full THR REF.

Note: ***Refer to the Airway Manual, Ops Specs, IAP, or the Company Pages, Critical Performance Procedures, Missed Approach/Rejected Landing table.

Note: ****Leave the TMC in GA, if another approach is warranted at the destination airport.

At typical landing weights, actual thrust required for a normal go-around is usually considerably less than maximum go-around thrust. This provides a thrust margin for windshear or other situations requiring maximum thrust. If full thrust is desired after thrust for the nominal climb rate has been established, press TO/GA a second time.

If a missed approach is required following a manual instrument approach, or a visual approach, push either TO/GA switch, call for flaps 20, ensure/set go-around thrust, and rotate smoothly toward 15° pitch attitude. 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 at 100 feet, approximately 40 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 or if the airplane is below 5 feet radio altitude for more than 2 seconds.

The TO/GA pitch mode initially commands a go-around attitude and then transitions to speed as the rate of climb increases. This speed is normally between command speed and command speed + 25 knots. The TO/GA roll mode maintains existing ground track. Above 400 feet AGL, select the roll mode as appropriate.

The minimum altitude for flap retraction during a normal takeoff is not normally applicable to a missed approach procedure. However, obstacles in the missed approach flight path must be taken into consideration. Use 1,000 feet AGL to initiate acceleration for flap retraction.

Note: Pitch and roll modes cannot be engaged until above 400 feet AGL.

Note: When accomplishing a missed approach from a multi-autopilot approach, initial selection of a roll mode, pitch mode, or when altitude capture occurs above 400 feet AGL, the autopilot reverts to single autopilot operation.

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.

Command speed should not be increased until a safe altitude and acceleration height is attained. Accelerate to flap retraction speed by selecting VNAV or FLCH and repositioning the command speed to the maneuver speed for the desired flap setting. Retract flaps on the normal flap/speed schedule. When the flaps are retracted and the airspeed approaches maneuver speed, select THR and ensure CLB thrust is set. Verify the airplane levels off at selected altitude and proper speed is maintained.

If VNAV ALT is displayed, a premature level off may occur and selection of FLCH may be required to complete the climb to the missed approach altitude.

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, Departure/Missed Approach/Rejected Landing Priorities and the Company Pages.



Go-Around Not Requiring a Climb (Approach Cancellation Prior to Descent)

Should an approach clearance be cancelled 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 HOLD) 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. Thrust and pitch commands provide for a climb of 2,000 fpm at go-around speed. Immediate modifications to the flight path can be made by selecting alternate pitch and roll modes if required (e.g., HDG SEL, FLCH). Alternatively, if approach mode (APP) has been selected and the localizer and glideslope have captured, pitch and roll modes other than TOGA cannot be selected unless the autopilot is disengaged and flight directors are turned OFF and back ON. The FMA will annunciate HDG HOLD and V/S. This can be done, however it requires a greater degree of coordination between the PF and PM.

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:

- If full go-around thrust is used, 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.
- The AFDS control laws 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 the autothrottle.
- Press TO/GA switch once to command thrust sufficient for a 2,000 fpm climb rate.

- If full go-around thrust is used, reduce to climb thrust earlier than normal.
- Disengage the AFDS 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 speedbrakes retract and autobrakes disarm as thrust levers are advanced. The F/D go-around mode will not be available until go-around is selected after becoming airborne.

Once reverse thrust is initiated following touchdown, a full stop landing must be made. If an engine stays in reverse, safe flight is not possible.

Landing

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Visual Approach Slope Indicator (VASI / T-VASI)

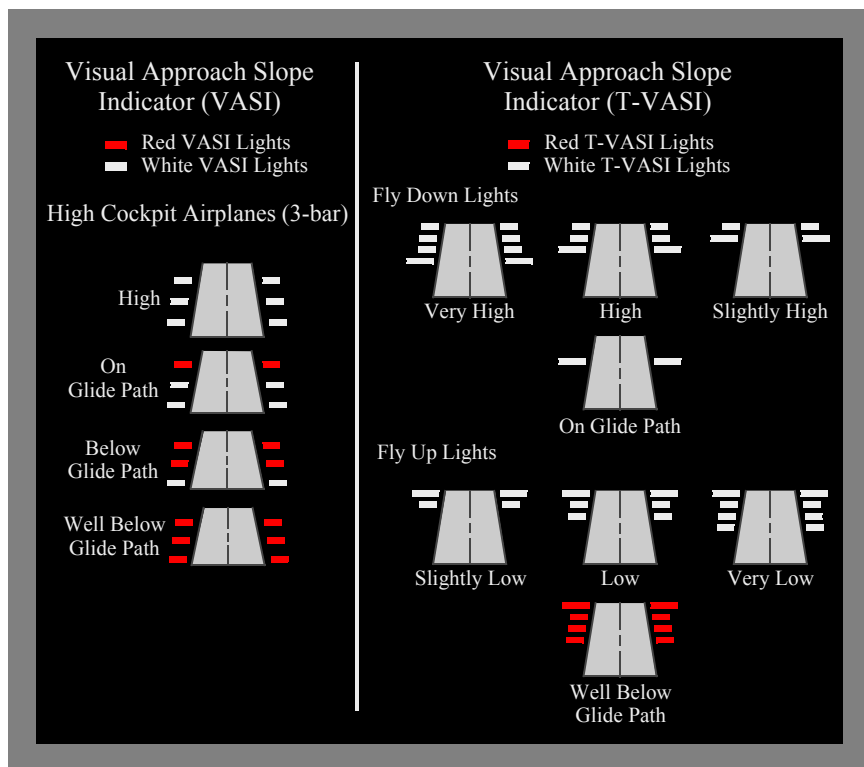
The VASI is a system of lights arranged to provide visual descent guidance information during the approach. All VASI systems are visual projections of the approach path normally aligned to intersect the runway at a point 1,000 or 1,800 feet beyond the threshold. Flying the VASI glide slope to touchdown 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 low approach with marginal threshold height. Therefore, the two-bar VASI system should not be used to determine proper approach profile. It may provide 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 one red bar over two white bars. 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



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 $1/4^\circ$ higher (3.25°). This higher glide path is intended for use only by high cockpit (long wheelbase) aircraft to provide a sufficient threshold crossing height.

Note: The use of a two bar VASI system is not recommended. A two bar VASI system provides a visual aim point that results in main landing gear touchdown at, or very near, the end of the runway threshold.

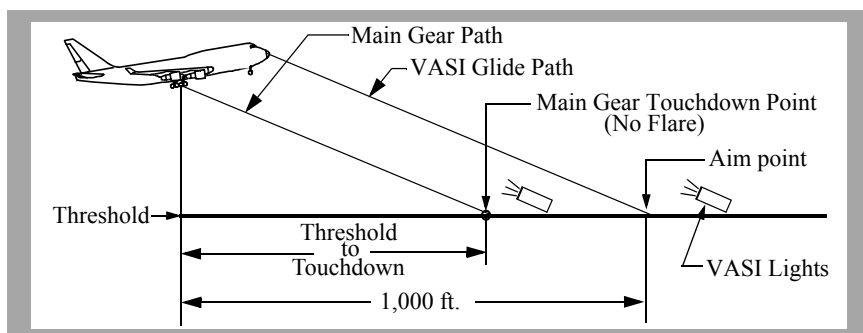
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Two Bar/Three Bar VASI Landing Geometry

The following diagrams use these conditions:

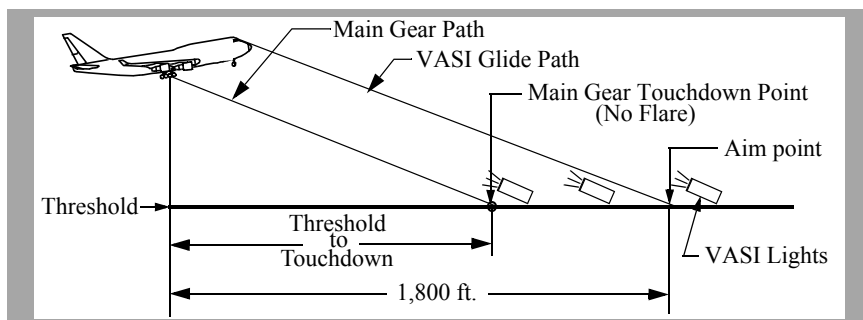
- data is based upon typical landing weight
- aircraft body attitudes are based on Flaps 30, VREF 30 + 5 and should be reduced by 1° for each 5 knots above this speed.
- pilot eye height is measured when the main gear is over the threshold.

Two Bar VASI Landing Geometry



747 Model	Flaps 30		Main Gear over Threshold		Threshold to Main Gear Touchdown Point - No Flare (feet)
	Visual Glide Path (degrees)	Airplane Body Attitude (degrees)	Pilot Eye Height (feet)	Main Gear Height (feet)	
-400	3.0	2.0	47	12	233

Three Bar (Upper Glide Path) VASI Landing Geometry



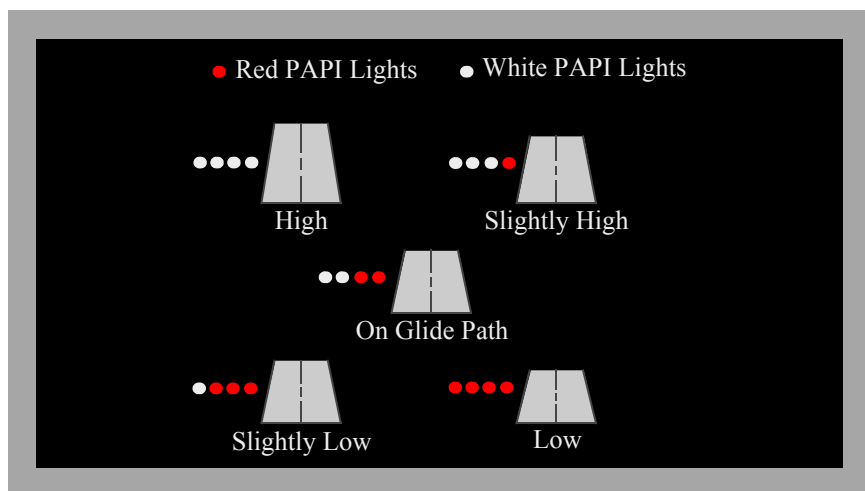
747 Model	Flaps 30		Main Gear over Threshold		Threshold to Main Gear Touchdown Point - No Flare (feet)
	Visual Glide Path (degrees)	Airplane Body Attitude (degrees)	Pilot Eye Height (feet)	Main Gear Height (feet)	
-400	3.25	1.8	97	62	1091

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



Landing Geometry

Visual Aim Point

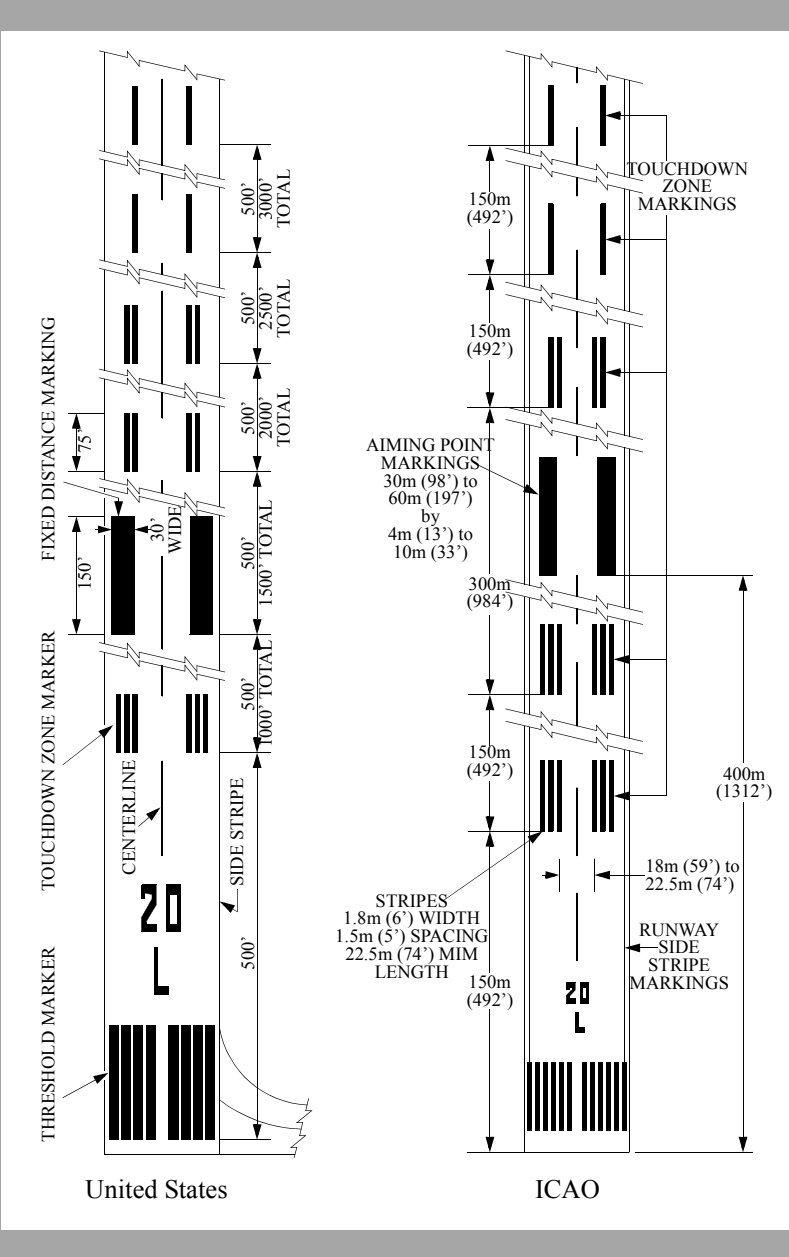
During visual approaches many techniques and methods are used to ensure main landing gear touchdown at the desired point on the runway. One of the most common methods used is to aim at the desired gear touchdown point on the runway, then adjust the final approach glide path until the selected point appears 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.

Runway Markings (Typical)

The following runway markings are for runways served by a precision approach.



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.

Note: Any time fuselage contact is suspected or known to have occurred, accomplish the appropriate NNC.

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 wing and body gear is often preferable to a soft touchdown with the nose rising rapidly.

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.



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 30 feet above the runway by increasing pitch attitude approximately 2° - 3° . This slows the rate of descent.

After the flare is initiated, smoothly retard the thrust levers 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 thrust levers 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 section 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.

Airspeed Control

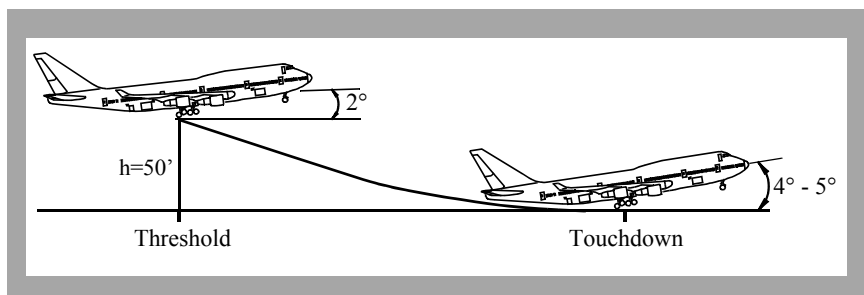
During an autoland, the autothrottle retards the thrust so as to reach idle at touchdown. The 5 knot additive is bled off during the flare.

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, and
- aircraft body attitudes are based upon typical landing weights, flaps 30, VREF 30 + 5 knots (approach) and VREF 30 + 0 (touchdown), and should be reduced by 1° for each 5 knots above this speed.



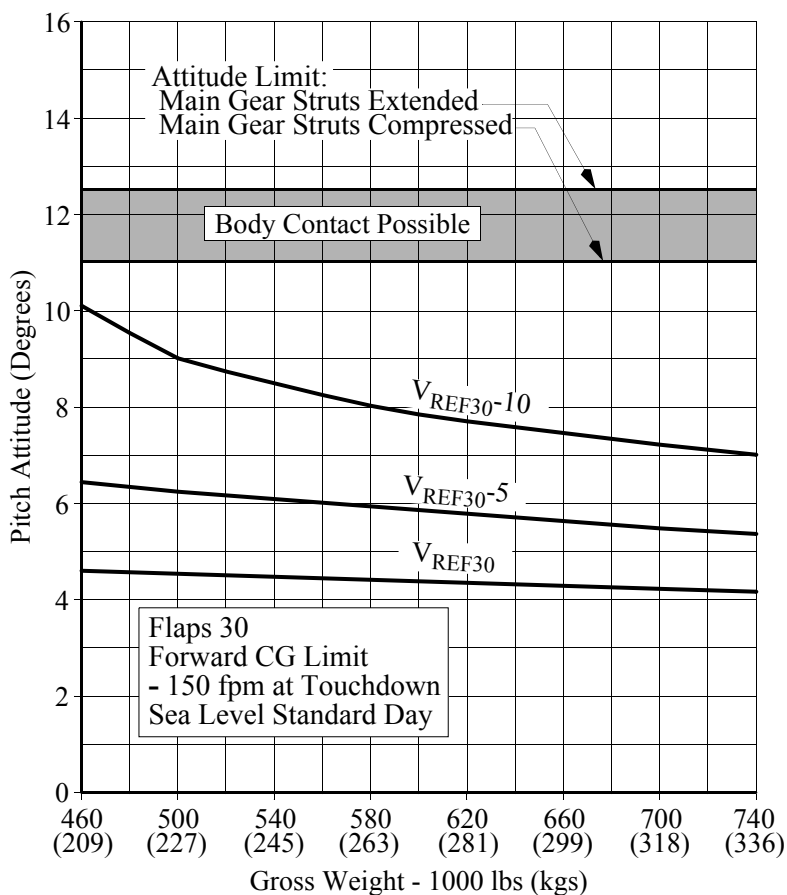
Normal Touchdown Attitude

The following figures illustrate the effect of airspeed on aircraft attitude at touchdown. They show aircraft attitude at a normal touchdown speed (VREF to VREF - 5 knots) for flaps 25 and flaps 30. The figures also show that touchdown at a speed below normal touchdown speed, in this case VREF - 10 knots, seriously reduces aft body-runway clearance.

Conditions

- Forward CG limit
- Sea level standard day
- -150 fpm sink rate at touchdown

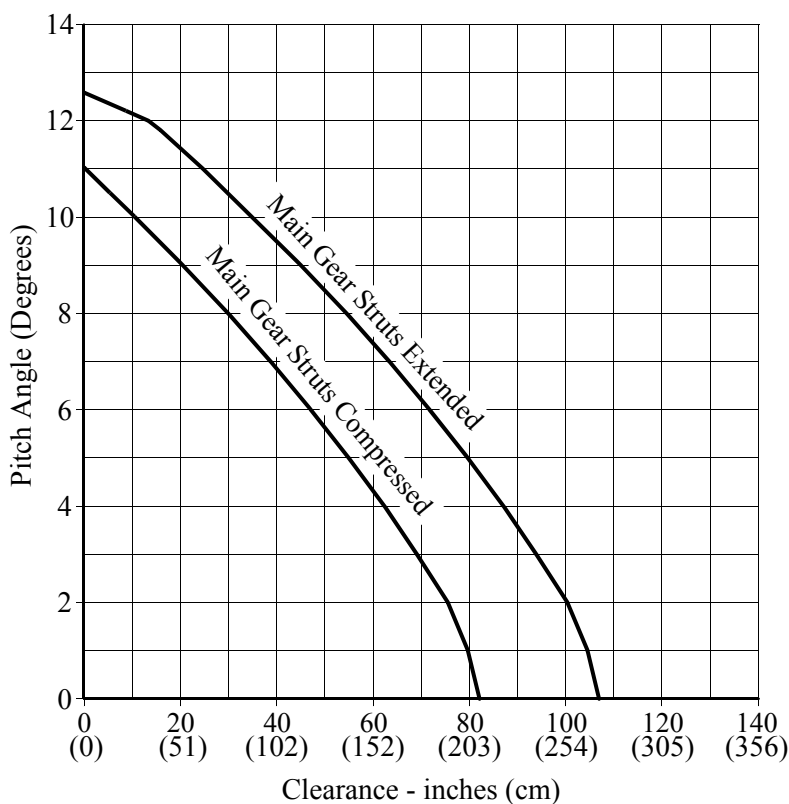
Touchdown Body Attitudes - Pounds



Body Clearance at Touchdown

The following figures show aft fuselage-runway clearance in relation to pitch angle with all main gear tires on the runway.

Body Clearance above Ground



Pitch and Roll Limit Conditions

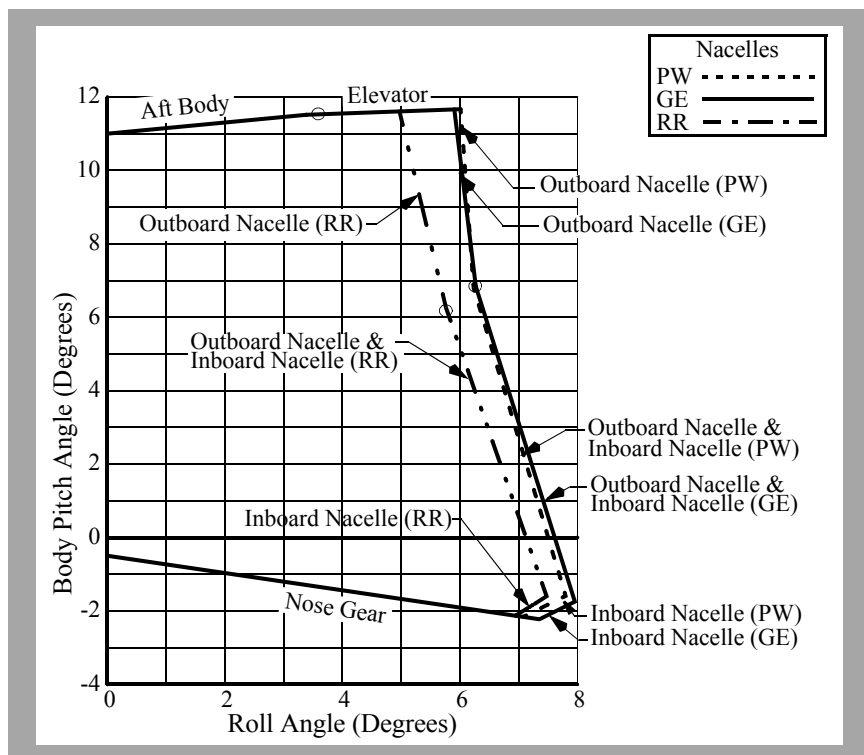
The Ground Contact Angles - Normal Landing figures illustrate body roll/pitch angles at which the aircraft structure contacts the runway.

Note: The figures are based on a rigid wing, however, dynamic maneuvering can reduce this envelope due to structural flexing of the airframe. Therefore, body roll/pitch angles within the envelope shown on the figures can result in aircraft structure contacting the runway.

Conditions

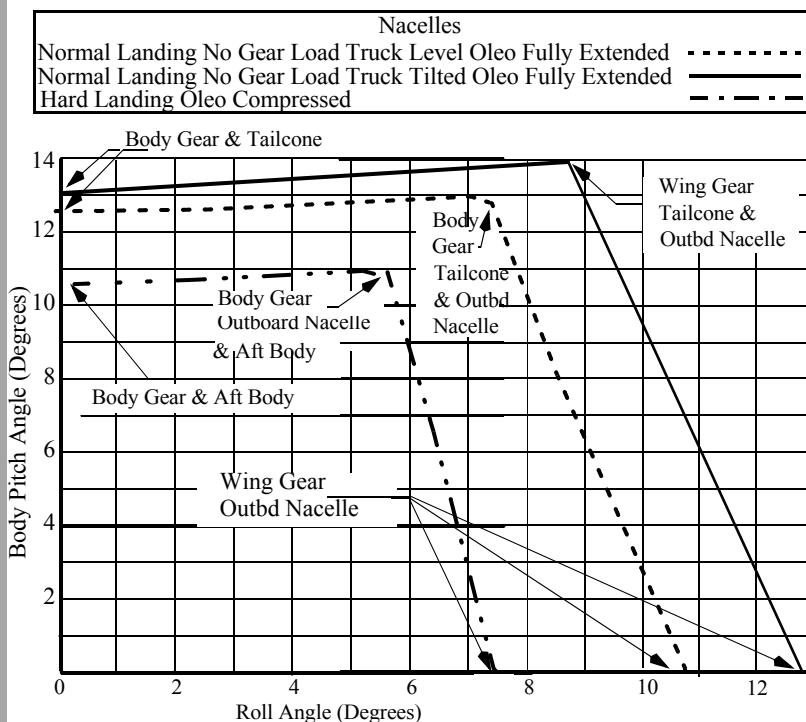
- Pitch about aft body gear centerline
- Struts fully compressed
- Valid for all control surface positions
- Roll about wing gear outside tire
- Valid for all flap detents

Note: Delta Air Lines' 747-400s are equipped with Pratt & Whitney (PW) engines.



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The following illustration provides the relationship between body pitch angle and body roll angle. It should be noted that as the pitch angle increases, the roll (bank) angle becomes more restrictive. At 0° of pitch, up to 7° of bank can occur before the outboard nacelle would contact the ground with a compressed oleo strut. However, as the pitch increases to 8-10°, the bank angle is reduced to approximately 5.5° for adequate surface clearance.



Bounced Landing Recovery

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 speedbrake deployment may be disabled even when the speedbrakes are armed. This can result in a bounced landing.

If the speedbrakes started to extend on the initial touchdown, they will retract once the airplane becomes airborne again on a bounce, even if thrust is not increased. The speedbrakes must then be manually extended after the airplane returns to the runway.

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

Avoid touching down with thrust above idle since this may establish an aircraft nose up pitch tendency and increases landing roll.

After main gear touchdown, initiate the landing roll procedure. If the speedbrakes do not extend automatically move the speedbrake lever to the UP position without delay.

Fly the nose wheels smoothly onto the runway without delay. Control column movement forward of neutral should not be required. Do not attempt to hold the nose wheels 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.

To avoid possible aircraft structural damage, do not make large nose down control column movements before the nose wheels are 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.

Speedbrakes

The speedbrakes can be fully raised after touchdown while the nose wheels are lowered to the runway, with no adverse pitch effects. The speedbrakes spoil the lift from the wings, which places the aircraft weight on the main landing gear, providing excellent brake effectiveness.

Unless speedbrakes 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.

Normally, speedbrakes are armed to extend automatically. Both pilots should monitor speedbrake extension after touchdown. A In the event auto extension fails, the speedbrake should be manually extended immediately.

Pilot awareness of the position of the speedbrake lever during the landing phase is important in the prevention of over-run. The position of the speedbrakes 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.

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. 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 tiller 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. Actual stopping distances for a maximum effort stop are approximately 60% of the dry runway field length requirement. 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, speedbrakes, wheel brakes, and surface conditions of the runway.

Note: Reverse thrust and speedbrake 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.

Note: Speedbrakes fully deployed, in conjunction with maximum reverse thrust and maximum manual antiskid braking provides the minimum stopping distance.

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.

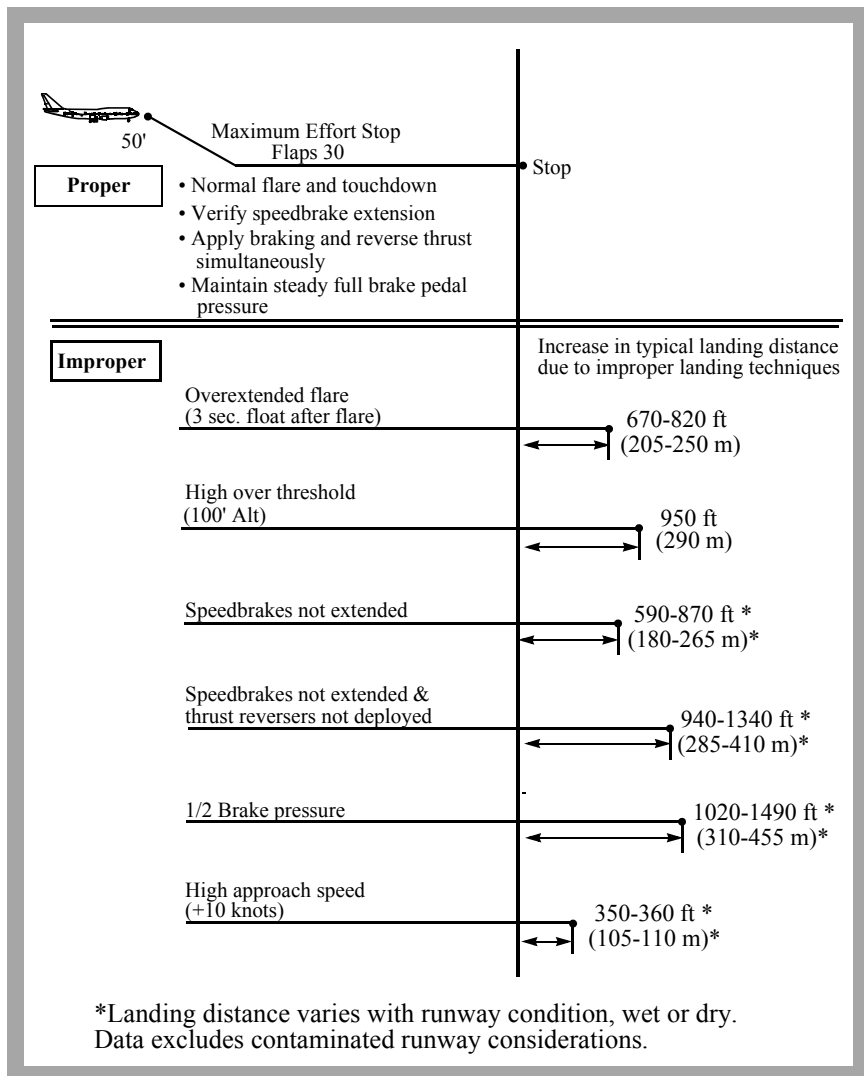
Reduced flaps landing increases landing distance. Landing distance assumptions and performance can be determined by referencing the ODM.

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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Factors Affecting Landing Distance (Typical)

The following diagrams show typical increases in landing distance due to improper landing techniques compared to the proper (baseline) condition. These data are based on dry runway, sea level, standard day conditions with landing weights up to the maximum landing weight. Data exclude wet or contamination effects. When increased landing distance is shown as a range, it reflects variations in aircraft weight and model variants (if applicable). These calculations are intended for training discussion purposes only.



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. Stopping distances for the various autobrake settings and for 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.

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.

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 speedbrakes.

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 recommended 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.

Settings include:

- **MAX AUTO:** Used when minimum stopping distance is required. Deceleration rate is less than that produced by full manual braking
- **3 or 4:** Should be used for wet or slippery runways or when landing rollout distance is limited
- **1 or 2:** These settings provide a moderate deceleration suitable for all routine operations.

Experience with various runway conditions and the related aircraft handling characteristics provide initial guidance for the level of deceleration to be selected.

Immediate initiation of reverse thrust at main gear touchdown and full reverse thrust allow the autobrake system to reduce brake pressure to the minimum level. Since the autobrake system senses deceleration 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.

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 Autobrake Landing Distance tables 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 aircraft deceleration rate, runway conditions, and stopping requirements. Normally the speedbrakes remain deployed until clearing the runway. When transitioning to manual braking, use reverse thrust as required until taxi speed. The use of speedbrakes 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.
- Manually position the autobrake selector off (normally done by the PM at the direction of the PF).
- Stow the speedbrake handle. When stopping distance within the remaining runway is assured, this method provides a smooth transition to manual braking, is effective before or after thrust reversers are stowed, and is less dependent on manual braking technique.

Manual Braking

The following technique for manual braking provides optimum braking for all runway conditions:

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

Immediately after main gear touchdown, smoothly apply a constant brake pedal pressure for the desired braking. 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.

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.

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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.

Carbon Brake Life

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.

For normal landing conditions, autobrakes 2 or 3 optimizes brake wear, passenger comfort, and stopping performance. Since autobrake settings apply the brakes dependant upon the deceleration rate, an autobrake setting of 1 results in a higher probability that the autobrakes will modulate, especially when the reversers are used. Autobrakes 2 or 3 results in a continuous brake application, which can increase carbon brake life.

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. Total in-flight cooling time can be determined from the ODM.

The brake temperature monitoring system may be used for additional flight crew guidance in assessing brake energy absorption. This system indicates a stabilized value approximately fifteen minutes after brake energy absorption. Therefore, an immediate or reliable indication of tire or hydraulic fluid fire, wheel bearing problems, or wheel fracture is not available. The brake temperature monitor readings may vary between brakes during normal braking operations.

Note: Brake energy data provided in the ODM should be used to identify potential overheat situations.

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.

Note: Autolands are not recommended for overweight landings.

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;
- use an autobrake setting, consistent with reported runway conditions, that will result in the use of all available runway length. A stopping distance safety margin should be used. 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;



- select maximum reverse thrust as soon as possible after main gear touchdown. Do not wait for nose wheel touchdown. The intention is to use reverse thrust as the major force that stops the aircraft. The use of maximum 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;
- consider extending the landing gear early to provide maximum brake cooling as needed.

Reverse Thrust Operation

WARNING: After reverse thrust is initiated, a full stop must be made.

Awareness of the position of the forward and reverse thrust levers must be maintained during the landing phase. Improper seat position as well as long sleeved apparel may cause inadvertent advancement of the forward thrust levers, preventing movement of the reverse thrust levers.

The purpose of the designed groove on each forward or reverse thrust lever knob is to accommodate each respective finger from the index finger through the small finger. The thumb is normally placed next to the inboard thrust lever knob. The grooves on the thrust lever knobs make it easier for the fingers to remain in position. A throttle system where the fingers are indexed to the grip of the hand lessens the chance of missing an individual lever when applying forward or reverse thrust. Mishandling is immediately obvious because the grip can't be completed correctly.

Manipulation of the thrust levers is similar to that used with two engines. If other techniques are used to manipulate the thrust levers, the potential for inadvertent movement of the thrust levers during the landing operation is possible. In either case the position of the hand should be comfortable, have easy access to the autothrottle disconnect switch, and the ability to control all thrust levers, forward and reverse, through the full range of motion.

Note: Reverse thrust is most effective at high speeds.

After touchdown, with the thrust levers at idle, rapidly raise the reverse thrust levers up and aft to the interlock position, then to the full reverse position. 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.

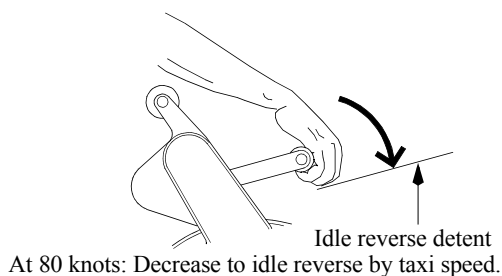
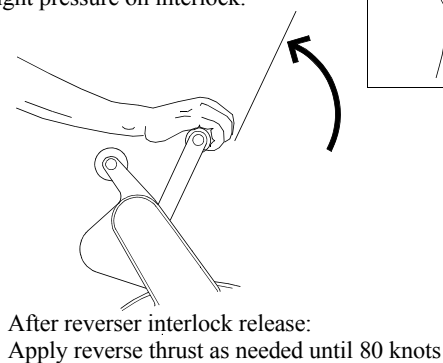
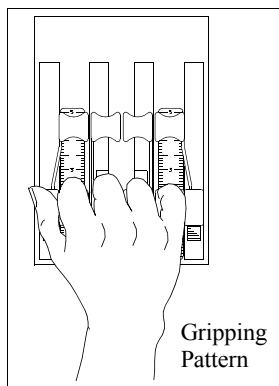
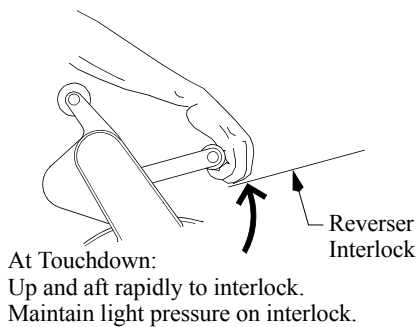
Maintain reverse thrust as required, up to maximum, until 80 knots. At this point start reducing the reverse thrust so that the reverse thrust levers are moving down at a rate commensurate with the deceleration rate of the aircraft. The thrust levers should be positioned to reverse idle by taxi speed, then to full down after the engines have decelerated to idle. Reverse thrust is reduced to idle between 80 knots and taxi speed, unless required for adverse conditions, to prevent engine exhaust re-ingestion and to reduce the risk of FOD. Engines 2 and 3 are particularly susceptible to FOD damage when operating at high reverse thrust levels, and low speeds, on contaminated or treated runways. 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 reverse thrust levers when deselecting reverse thrust may cause engine stalls (surges).

Note: If an engine surges during reverse thrust operation, quickly select reverse idle on all engines.

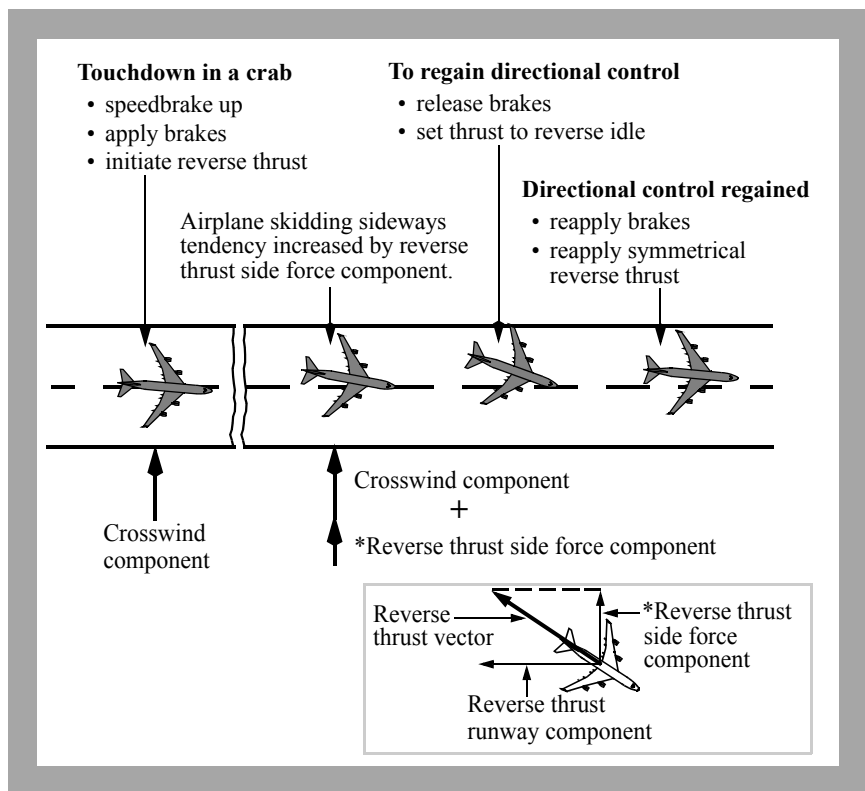
The PM should call out 80 knots to assist the PF in scheduling the reverse thrust. The PM should also call out any inadvertent selection of forward thrust as reverse thrust is cancelled.

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Reverse Thrust Operations



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 - EEC in the Alternate Mode

Use normal reverse thrust techniques, modulating reverse levers as required to remain within maximum N1 limits computed by the FMS and displayed on the engine instruments.

Reverse Thrust - One or Two Engines Inoperative

Symmetrical reverse thrust should be used with one or two engines inoperative, if possible. Use normal reverse thrust procedures and techniques. All thrust levers may be brought to the reverse idle position; then apply reverse thrust on symmetrical engines as needed. If stopping distance is critical, asymmetrical reverse thrust may be used. However, if directional control becomes a problem during deceleration, return the thrust levers to the reverse idle detent.

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

WARNING: Do not exceed 5 degrees of bank during landing and rollout to avoid an outboard engine pod striking the ground.

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.

Sideslip only (zero crab) landings are not recommended with crosswind components in excess of 20 knots. This recommendation ensures adequate ground clearance and is based on maintaining adequate control margin.

Crosswind Landing Techniques

Three methods of performing crosswind landings are presented. They are the de-crab technique (with removal of crab in flare), touchdown in a crab, 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.

Touchdown In Crab

The aircraft can land using crab only (zero sideslip) up to the landing crosswind guideline speeds.

On dry runways, upon touchdown the aircraft tracks toward the upwind edge of the runway while de-crabbing to align with the runway. Immediate upwind aileron is needed to ensure the wings remain level while rudder is needed to track the runway centerline. The greater the amount of crab at touchdown, the larger the lateral deviation from the point of touchdown. For this reason, touchdown in a crab only condition is not recommended when landing on a dry runway in strong crosswinds.

On very slippery runways, landing the aircraft using crab only reduces drift toward the downwind side at touchdown, permits rapid operation of spoilers and autobrakes because all main gears touchdown simultaneously, and may reduce pilot workload since the aircraft does not have to be de-crabbed before touchdown. However, proper rudder and upwind aileron must be applied after touchdown to ensure directional control is maintained.

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. 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.

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 engine nacelle or outboard wing flap to contact the runway. Refer to Ground Contact Angles - Normal Landing 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.

If the crew elects to fly the sideslip to touchdown, it may be necessary to add a crab during strong crosswinds. Main gear touchdown is made with the upwind wing low and crab angle applied. As the upwind gear touches first, a slight increase in downwind rudder is applied to align the aircraft with the runway centerline. At touchdown, increased application of upwind aileron should be applied to maintain wings level.

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 25 or 30 landings at all gross weights. However, wet or slippery runway field length requirements should be verified from the landing distance charts in the ODM. Brake energy limits will not be exceeded for flaps 25 or 30 landings at all gross weights.

Note: If flaps 30 approach speed ($V_{REF} 30 + \text{additives for wind and gusts}$) is higher than 167 knots, use flaps 25 and $V_{REF} 25$ for landing.

If stopping distance is a concern, reduce the landing weight as much as possible. At the captain's discretion, consider fuel jettison or reduce weight by holding at low altitude with a high drag configuration (gear down) to achieve maximum fuel burn-off.

When landing at high gross weights at speeds associated with non-normal procedures requiring flaps set at 25 or less, maximum effort stops may exceed the brake energy limits. The gross weights where this condition can occur are well above maximum landing weights. For these non-normal landings, maximize use of the available runway for stopping.

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.

Note: For overweight landings, flaps up command speed should be set no lower than $UP + 20$.

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. At weights above the maximum landing weight, the final approach maximum wind additive may be limited by the flap placards and load relief system.



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.

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; and
- 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.

Intentionally
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Maneuvers

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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, and
- 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 thrust levers 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.

Engine Out Familiarization

Two Engine Out Familiarization

The exercise shown in the following table is performed to develop proficiency in handling the airplane with two engines inoperative and gain familiarization with rudder control requirements.

	Condition
Airspeed	Flaps up maneuvering speed
Landing Gear	Up
Flaps	Up
Thrust	As Required
When In Trim - Retard two thrust levers to idle Controls - Apply to maintain heading, wings level Rudder - Apply to center control wheel Airspeed - Maintain with thrust Trim - As required to relieve control forces	

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.

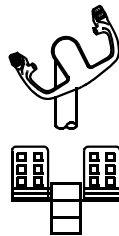
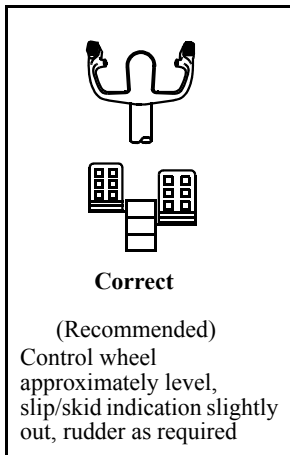
If the aircraft is trimmed with too much control wheel displacement, full lateral control is not available and spoilers on one wing may be raised, increasing drag.

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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.

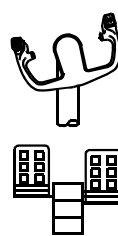
The following figure shows correct and incorrect use of the rudder.

If an engine(s) 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.



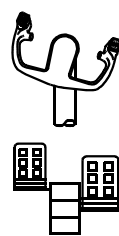
Incorrect

Wheel only
 No rudder



Incorrect

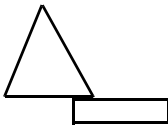
Not enough
 rudder



Incorrect

Too much
 rudder

Condition: Engine out right wing.



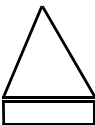
— push rudder until



lines up with



(i.e. put your foot in the boat)



— correct position

- if kept in this position the aircraft performs correctly



Thrust and Airspeed

If not thrust limited, apply additional thrust, if required, to control the airspeed. The total four-engine EPR 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.

Note: Autothrottle can be used effectively with an engine inoperative as long as the autopilot is engaged and yaw is controlled with rudder.

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: A 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 0.88M to 0.90M. 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.

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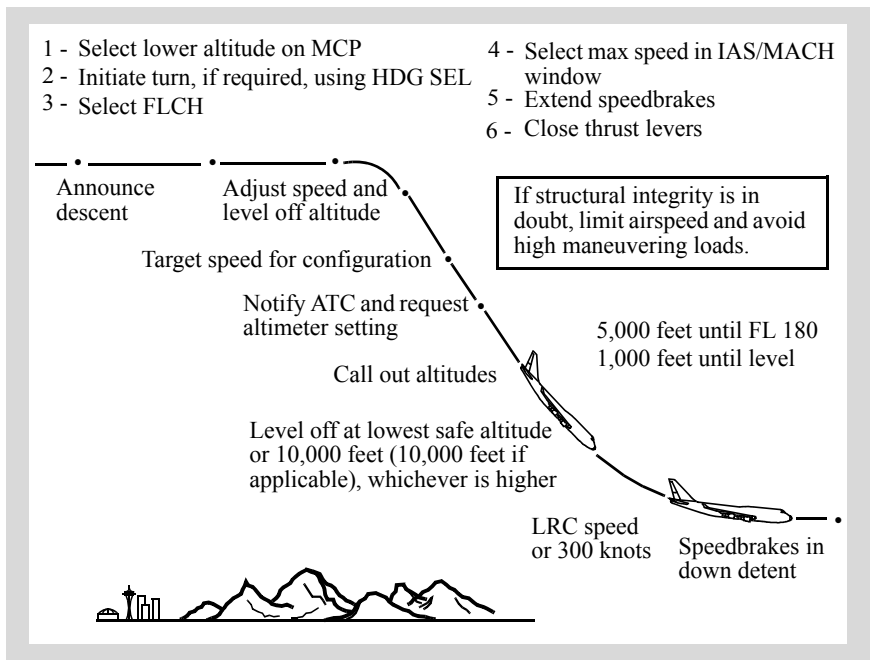
Rapid Descent

This section addresses basic techniques and procedures for a rapid 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.

Rapid 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.

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: Rapid 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

Flight Level Change (FLCH)

Because of airspeed and altitude protection and reduced crew workload, use of the autopilot with FLCH mode is the recommended technique for rapid descents. Use of the V/S mode is not recommended.

Initiate a turn, if required, using HDG SEL. Set a lower altitude in the altitude window. Select FLCH, verify speed in IAS/Mach window, close the thrust levers and smoothly extend the speedbrakes. If turn radius is a factor, the pilot should manually select the desired bank angle required to complete the maneuver in a safe manner. Autothrottles should be left engaged. The aircraft pitches down smoothly while the thrust levers retard to idle. Adjust the speed as needed and ensure the altitude window is correctly set for the level off. During descent, the IAS/MACH speed window changes from MACH to IAS at approximately 310 KIAS. Manually reset to VMO as needed.

When descending at speeds near VMO/MMO with the autopilot engaged, short-term airspeed increases above VMO/MMO may occur. These are most often due to wind and temperature changes. These short-term increases are acceptable for this maneuver and the autopilot should adjust the pitch to correct the airspeed to below VMO/MMO. Do not disconnect the autopilot unless autopilot operation is clearly unacceptable. Any airspeed above VMO/MMO should be documented in the aircraft logbook.

Note: For more complete information on recommendations if VMO/MMO is exceeded, see the section titled “Overspeed” in chapter 8 of this manual.



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When approaching the target altitude, ensure the altitude is set in the MCP altitude select window, and the command speed is set to LRC or approximately 300 knots before level-off is initiated. This aids in a smooth transition to level flight. When the speedbrakes are retracted during altitude capture near VMO/MMO, a momentary overspeed condition may occur. 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.

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 display and bank angle to ensure that at least minimum maneuver speed is maintained when turning.

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 thrust levers 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 reaching level flight add thrust to maintain long range cruise or 300 knots.

Landing Gear Extended Descent

The rapid descent is normally made with the landing gear up. However, when structural integrity is in doubt and airspeed must be limited, extension of the landing gear may provide a more satisfactory rate of descent.

If the landing gear is to be used during the descent, comply with the landing gear placard speeds. Landing gear placard speeds may be below minimum maneuver speeds at high gross weights. Limit bank angle to 15° of bank when below minimum maneuver speed.

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.

Flight Control Effectiveness

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, and
- loaded/unloaded roll demonstration.

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.).

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.

Stall or Approach to Stall

Stall or Approach to Stall Recovery Maneuver

All recoveries from approach to stall should be done as if an actual stall has occurred.

Immediately accomplish the following at first indication of stall buffet or stick shaker.

Note: Do not use flight director commands during the recovery.

Note: When displayed (flaps not up) the Pitch limit Indicator indicates the limit when stick shaker occurs for existing flight conditions.


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Pilot Flying	Pilot Monitoring
- Initiate recovery. - Hold the control column firmly - Disconnect autopilot and autothrottles - Smoothly apply nose down elevator to reduce the angle of attack until buffet or stick shaker stops. Nose down stabilizer trim may be needed.*	- Monitor altitude and airspeed. - Verify all required actions have been done and call out any omissions. - Call out any trend toward terrain contact.
- Continue the recovery. - Roll in the shortest direction to wings level if needed.** - Advance thrust levers as needed. - Retract the speedbrakes. - Do not change gear or flap configuration, except - During liftoff, if flaps are up, call for flaps 1.	- Monitor altitude and airspeed. - Verify all required actions have been done and call out any omissions. - Call out any trend toward terrain contact. - Set the FLAP lever as directed.
- Complete the recovery. - Check airspeed and adjust thrust as needed. - Establish pitch attitude. - Return to the desired flight path. - Re-engage the autopilot and autothrottle if desired.	- Monitor altitude and airspeed. - Verify all required actions have been done and call out any omissions. - Call out any trend toward terrain contact.

WARNING: * If the control column does not provide the needed response, stabilizer trim may be necessary. Excessive use of pitch trim may aggravate the condition, or may result in loss of control or in high structural loads.

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.

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.

A stall warning should be readily identifiable by the pilot, either by initial buffet or an artificial indication (stick shaker). During the initial stages of a stall, local airflow separation results in buffeting (initial buffet), giving a natural warning of an approach to stall. At cruise Mach speed, stick shaker activation occurs just after reaching initial buffet. Recovery from an approach to stall should be initiated at the earliest recognizable stall warning, either initial buffet or stick shaker.

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.

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; and
- inability to arrest descent rate.

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.

Note: With high thrust engines, low airspeed coupled with high thrust settings may result in a condition where elevator authority is not adequate. This is because aircraft with underwing-mounted engines have a nose-up pitch moment relative to increased thrust.

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 thrust levers as needed. Under certain conditions, where high thrust settings are already applied such as during takeoff or go-around, it may be necessary to reduce thrust in order to prevent the angle of attack from continuing to increase. This is because aircraft with underwing-mounted engines have a nose-up pitch moment relative to increased thrust.

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 flaps 1 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.

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 and stabilizer trim is required to initiate a descent. 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 airspeed at 280 knots on heading and altitude. Use a normal turn entry. An increase in pitch is required as the bank angle is increased to maintain constant altitude. An increase in thrust is required to maintain constant airspeed.

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. If desired, the flight path vector (FPV) may be used to assist in positive aircraft control. Since the symbol is the aircraft's velocity vector, center the FPV circle on the horizon line of the PFD to maintain level flight.

Vertical Speed Indicator

IRS vertical speed indications provide immediate trend information.

Altimeter

Crosscheck the direction and rate of change, and make smooth minor adjustments to the pitch attitude for corrections.



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 speed tape. 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.



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 Look-ahead terrain alerting 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 OBSTACLE
- CAUTION TERRAIN
- SINK RATE
- TERRAIN
- DON'T SINK
- TOO LOW FLAPS
- TOO LOW GEAR
- TOO LOW TERRAIN
- GLIDESLOPE
- BANK ANGLE

Pilot Flying	Pilot Monitoring
Correct flight path or airplane configuration.	

The below glideslope deviation alert may be cancelled or inhibited for:

- localizer 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 “PULL UP” warning
- activation of “TERRAIN TERRAIN PULL UP” warning
- other situations resulting in unacceptable flight toward terrain.

Pilot Flying	Pilot Monitoring
Disengage autopilot. Disconnect autothrottle. Aggressively apply maximum* thrust. Simultaneously roll wings level and rotate to an initial pitch attitude of 20°.	Verify maximum* thrust. Verify all required actions have been completed and call out any omissions.
Retract speedbrakes. If terrain remains a threat, continue rotation up to the pitch limit indicator or stick shaker or initial buffet.	
Do not change gear or flap configuration until terrain separation is assured. Monitor radio altimeter for sustained or increasing terrain separation. When clear of 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: Aft control column force increases as 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.

Note: * Maximum thrust can be obtained by advancing the thrust levers full forward when the EECs are in the normal mode. If terrain contact is imminent, advance thrust levers full forward.

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** warning, the alert may be regarded as cautionary and the approach may be continued.

** as installed

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 any portion of the aircraft symbol is within the red region on the attitude indicator (as installed) or if the existing vertical speed is in the red band (RA VSI) (as installed).

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.



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 20" • Call for "GEAR UP" • Accelerate, call for flap retraction on schedule • After Takeoff checklist	• Make MCP and configuration changes as requested by the PF



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.



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.



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 the airplane is not stalled. A stalled condition can exist at any altitude 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.



Nose High Recovery

Pilot Flying	Pilot Monitoring
Recognize and confirm the situation	
- Disengage autopilot and disconnect autothrottle - Apply as much as full nose-down elevator *Apply appropriate nose-down stabilizer trim - Reduce thrust *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 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.



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, and
- 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. Further complicating this situation, as the airspeed decreases, the pilot could intuitively make a large thrust increase. This causes an additional pitch up. 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. If altitude permits, flight tests have determined that an effective way to achieve a nose-down pitch rate is to reduce some thrust.



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° .

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.

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.

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 full rated takeoff thrust (TO) and the flap setting selected by AWABS for the runway in use.
- Use the longest suitable runway provided it is clear of areas of known windshear.
- Use the flight director after takeoff.
- 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.
- 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

- Use either Flaps 25 or 30 for landing.
- 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, VNAV path or VASI/PAPI indications to detect flight path deviations and help with timely detection of windshear.
- If the autothrottle is disengaged, or is planned to be disengaged prior to landing, 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.

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.



Windshear Encounter Recognition

Note: The following are indications the airplane is encountering a windshear:

- 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 thrust lever position for a significant period of time.



Windshear Escape Maneuver

Pilot Flying	Pilot Monitoring
• Disconnect autopilot. • Press either TO/GA switch. • Aggressively apply maximum* thrust. • Disconnect autothrottle. • Simultaneously roll wings level and rotate toward an initial pitch attitude of 15 °. • Retract speedbrakes. • Follow flight director TO/GA guidance (if available)	• Assure maximum *thrust. • Verify all required actions have been completed and call out any omissions.
• 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.

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: *Maximum thrust can be obtained by advancing the thrust levers full forward if the EEC's are in the normal mode. If terrain contact is imminent, advance thrust levers full forward.

Windshear During Takeoff Roll

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. Once airborne, perform the Windshear Escape Maneuver.

Windshear In Flight

After Takeoff

Windshear encounter

- perform the Windshear Escape Maneuver.

On Approach

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, and
- complete the normal checklist (After Takeoff).

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Non-Normal Operations
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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 EICAS messages 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.

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 an EICAS alert message 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.

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 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.

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 on a four-engine aircraft are slightly more flexible than for two-engine aircraft. If not more than one engine has failed or is shutdown, most regulatory agencies specify that the pilot in command may proceed to another airport if, after considering weather, aircraft condition, fuel remaining, air traffic, and other pertinent factors, the chosen course of action is as safe as landing at the nearest suitable airport.

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.

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 AM, 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 primary HF frequency or 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.

On primary HF, try to obtain information on ship location through USCG, Navy, AMVER, or RCC. If a merchant ship is nearby, attempt to communicate on 4125 or 2182 kHz. 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.

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.

Note: Fuel jettisoning may also be considered prior to ditching.

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 30 or landing flaps 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.

Electrical

Approach and Landing on Standby Power

The probability of a total and unrecoverable power failure is remote. During training, or in the unlikely event that a landing must be made on standby power, the following guidelines should be considered.

Complete all applicable NNCs and the Standby Power Approach and Landing checklist in the QRH. The left side communications radio, navigation radio, and CDU are operable on standby power. On some aircraft, the left FMS is also operable.

Note: Refer to Vol. 2, chapter 6, for a list of significant equipment powered by standby power.

The EICAS displays numerous alert messages associated with the loss of all AC power. During the approach, the FLAPS DRIVE message displays after the flaps are selected to 1. The leading edge devices require AC control and cannot be extended on standby power. Use the FLAPS DRIVE NNC to determine the adjusted VREF and landing flap setting.

The control wheel trim switches are inoperative; however, the alternate trim switches on the aisle stand are operable. The right inboard and outboard trailing edge flaps indication is available, but trailing edge flap indication on the left side is not.

Fly the approach on speed. Antiskid is not available, and with the higher approach speed, any excess speed is undesirable. Auto speedbrakes and thrust reversers are not available.

Engines, APU

Engine Failure versus Engine Fire After Takeoff

The NNC for an engine failure is normally accomplished after the flaps have been retracted 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 thrust lever 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 the flaps have been retracted 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.

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 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 Limit or Surge or 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 thrust lever 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 thrust lever condition. This fixed RPM or thrust lever condition may be very near the commanded thrust level and therefore difficult to recognize until the flight crew attempts to change thrust. Other engine responses include: shutdown, operation at low RPM, or thrust at the last valid thrust lever setting (in the case of a thrust lever feedback fault) depending on altitude or air/ground logic. In all cases, the affected engine does not respond to thrust lever 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.

Multiple Engine Failure

Multiple 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.

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 MULTIPLE ENGINE FLAMEOUT OR STALL NNC is written to ensure that flight crews take advantage of the high RPM at engine failure regardless of altitude or airspeed.

Controllability With Loss of All Engine Thrust (Engines Windmilling)

Minimum demonstrated controllable airspeed with loss of all engine thrust is 160 knots. Observe a minimum speed of 160 knots or minimum maneuver speed, whichever is greater. Flaps are inoperative with all engines inoperative. Extending the landing gear with all engines inoperative may decrease the hydraulic pressure below that needed to operate the flight controls while the gear is being extended.

Note: Extend the gear only if one or more engines have started.

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.

The impact of a vibrating environment on human performance is dependent on a number of factors, including the orientation of the vibration relative to the body. People working in a vibrating environment may find relief by leaning forward or backward, standing, or otherwise changing their body position.

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:

When an engine shutdown is needed, the PF verbally coordinates confirmation of the affected engine with the PM and then slowly retards the thrust lever of the engine that will be shut down.

Coordinate activation of the fuel control switch as follows:

- PM places a hand on and verbally identifies the fuel control switch for the engine that will be shut down.
- PF verbally confirms that the PM has identified the correct fuel control switch.
- PM moves the fuel control switch to cutoff.

If the NNC requires activation of the engine fire switch, coordinate as follows:

- PM places a hand on and verbally identifies the engine fire switch for the engine that is shutdown.
- PF verbally confirms that the PM has identified the correct engine fire switch.
- PM pulls the engine fire switch.

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.
- 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 thrust lever in an attempt to control the exceedance. Retarding the thrust levers after thrust is set invalidates takeoff performance. When the PF judges that altitude (minimum 400 feet AGL) and airspeed are acceptable, the thrust lever should be retarded until the exceedance is within limits and the appropriate NNC accomplished. Enter the exceedance in the aircraft logbook.

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.

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.

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 flight deck emergency preparation as conditions dictate. • Fasten seat belt and shoulder harness and lock. • 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 flight deck emergency preparations as directed by the captain and as conditions dictate. • Fasten seat belt and shoulder harness and lock. • If ditching: don life vest.
Relief Pilot (When Aboard)	
• Assist in flight deck emergency preparations as directed by the captain and as conditions dictate. • Open flight deck door. Stow loose articles. • Fasten seat belt and shoulder harness and lock. • If ditching: don life vest.	

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Post Landing	
Captain	First Officer
• Order evacuation. • Proceed to forward cabin area. • 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. • Assume command outside the aircraft.	• Proceed to forward entry/exit door area. • Ensure forward exits are open. • Exit aircraft from forward exit and assist in the evacuation from outside the aircraft.
Relief Pilot (When Aboard)	
• Proceed to forward entry/exit door area. • Ensure forward exits are open. • Exit aircraft from forward exit and assist in the evacuation from outside the aircraft.	

Post Ditching	
Captain	First Officer
• Order evacuation. • Proceed to forward cabin area. • 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. • After exiting, assemble passengers/rafts away from the aircraft.	• Take portable ELT from 2L. • Ensure forward exits are open. • Exit aircraft from forward exit and board raft. • Assist in assembling passengers/rafts away from the aircraft.
Relief Pilot (When Aboard)	
• Direct passengers, and exit aircraft, through 2R door; board slide raft. • Assist in assembling passengers/rafts away from aircraft.	

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.

Note: When leading edge devices or trailing edge flaps are not in the proper position for flaps 25 or 30, autolands are not certified.

Note: Maximum tire speed is 204 knots.

All Flaps Up Landing

The probability of both leading and trailing edge devices failing to extend is extremely remote. System reliability and design have reduced the need for some traditional non-normal landing procedures. As a result, an all flaps up landing NNC was not required for aircraft certification and does not appear in the QRH.

Flaps Drive Failure (Leading Edge) - Landing

Failure of the primary pneumatic drive for the inboard, midspan, or outboard leading edge flaps causes the failed portion to automatically revert to the secondary mode (electric drive). The EICAS message FLAPS PRIMARY is displayed. If the flaps fail to respond in the electric drive mode or an asymmetry exists, the EICAS message FLAPS DRIVE is displayed. The FLAPS DRIVE NNC accommodates the most severe malfunction of no leading edge flaps on one wing.

Flaps 1 position operates only inboard and midspan leading edge flaps. When the flap lever is moved to the Flaps 1 detent and the leading edge inboard and/or midspan flaps fail to extend, the flap indication expands. The flap position indicator displays the expanded leading edge flap position by group.

The adjusted VREF specified in the QRH permits the approach to be flown wings level with the control wheel approximately level. Aircraft pitch attitude at touchdown is less than normal. Do not allow the aircraft to float. Fly the aircraft onto the runway at the desired touchdown point. Expeditiously accomplish the landing roll procedure after touchdown.

Flap Drive Failure (Trailing Edge) - Landing

Failure of the primary hydraulic drive for either the inboard or outboard trailing edge flaps causes the failed portion to automatically revert to the secondary mode (electric drive). If the flaps fail to respond in the electric drive mode or an asymmetry exists, the EICAS message FLAPS DRIVE is displayed. Accomplish the FLAPS DRIVE NNC.

The operable flaps should be positioned on schedule to flaps 25 for landing. The final approach speed corrected for wind may exceed the flap load relief speed at times. Expect a slight nose-down pitch change with outboard flap extension or a slight nose-up pitch change when inboard flaps are extended. If the pitch change requires a trim change which exceeds the main trim capability, the alternate trim switches may be used.

Avoid excessive speed above landing reference speed on final with minimum outboard flaps to prevent exceeding nose-down trim capability.

The adjusted VREF listed in the FLAPS DRIVE NNC allows normal maneuvering throughout the initial phases of the approach. On final, maintain adjusted VREF plus wind additive. If speed is allowed to decrease to adjusted VREF, 40° bank capability is not available.

The pitch attitude on final is several degrees higher than for normal configuration.

Do not allow the airspeed to go below adjusted VREF during the flare or the tail of the aircraft may contact the runway. Do not allow the aircraft to float just above the runway surface. Fly the aircraft onto the runway at the recommended touchdown point. Expeditiously accomplish the landing roll procedure after touchdown.

Flap Extension using the Secondary or Alternate System

When extending the flaps using the secondary or alternate system, the recommended method for setting command speed differs from the method used during normal flap extension. Since the flaps extend more slowly when using the secondary or alternate system, it is recommended that the crew delay setting the new command speed until the flaps reach the selected position. This method may prevent the crew from inadvertently getting into a low airspeed condition if attention to airspeed is diverted while accomplishing other duties.

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, and
- 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.

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: Alternate stabilizer trim is available in the unlikely event of insufficient, or loss of thumb switch trim command capability.

Note: Asymmetric engine thrust may aid roll and directional control.

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, control forces will be significantly greater than normal and control response will be slower than normal to flare the aircraft.

Go-Around Procedure

If the elevator is known or suspected to be jammed, a go-around should be avoided if at all possible. 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.

Jammed Stabilizer

The Jammed Stabilizer Landing NNC provides an adjusted approach speed for landing with a jammed stabilizer under the most adverse conditions. Prior to the approach, maintain in-trim speed as long as possible to reduce crew workload. As airspeed is reduced, a pull force is needed on the control column. Throughout the approach, the PM can assist with pitch control, as needed. Recheck stabilizer trim operation prior to landing to determine if the malfunction still exists. Do not allow the aircraft to float. Fly the aircraft onto the runway at the desired touchdown point. Aircraft pitch attitude at touchdown is less than normal because airspeed is higher than normal. Expeditiously accomplish the landing roll procedure after touchdown. If a go-around is necessary, accomplish normal go-around procedures and accelerate to in-trim speed.

Unscheduled Stabilizer Trim

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 column is 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.

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.

The primary purpose for fuel balance alerts is to inform the crew that imbalances beyond the current state may result in increased trim drag and higher fuel consumption. The FUEL IMBALANCE NNC should be accomplished when the fuel balance alert is received.

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 Considerations

The crew should consider the following when performing fuel balancing procedures:

- Use of the Fuel Balancing 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.
- Select the fuel page on the lower EICAS in order to monitor fuel loads.
- 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.).

Fuel Leak

Any time an unexpected fuel quantity indication, FMS or EICAS 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. The Fuel Leak NNC includes steps for a leak that is between the front spar and the engine (an “engine fuel leak”) or a leak from the tank to the outside (a “tank leak”). An engine fuel leak is the most common type of fuel leak since fuel lines are exposed in the strut. Most other fuel lines, such as a crossfeed manifold, are contained within the tanks. A significant fuel leak directly from a tank to the outside is very rare due to the substantial wing structure that forms the tanks.

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 NNC.

The NNC leads the crew through steps to determine if the fuel leak is from the strut or the engine area. If an engine fuel leak is confirmed, the NNC directs the crew to shut down the affected engine. There are two reasons for the shutdown. The first is to close the spar valve, which stops the leak. This prevents the loss of fuel which could result in a low fuel state. The second reason is that the fire potential is increased when fuel is leaking around the engine. The risk of fire increases further when the thrust reverser is used during landing. The thrust reverser significantly changes the flow of air around the engine which can disperse fuel over a wider area.

Low Fuel

A low fuel condition exists when the indicated fuel quantity in any main tank is 2,000 pounds 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.

Fuel Jettison

Fuel jettison should be considered when situations dictate landing at high gross weights and adequate time is available to perform the jettison. When fuel jettison is to be accomplished, consider the following:

- Ensure adequate weather minimums exist at airport of intended landing.
- Fuel jettison above 4,000 feet AGL ensures complete fuel evaporation.
- Downwind drift of fuel may exceed one nm per 1,000 feet of drop.
- Avoid jettisoning fuel in a holding pattern with other aircraft below.
- If maximum performance capability is required, jettison fuel to standpipe level.

Hydraulics

Proper planning of the approach is important. Consideration should be given to the effect the inoperative system(s) has on crosswind capabilities, autoflight, stabilizer trim, control response, control feel, reverse thrust, stopping distance, go-around configuration, and performance required to reach an alternate airfield.

Hydraulic System(s) Inoperative - Landing

If the landing gear is extended using alternate gear extension, the affected gear cannot be raised. Flaps can be extended or retracted using the secondary drive system. However, the rate of flap travel is significantly reduced. Flap extension from 0 to 5 may take as long as 4 minutes.

Flaps 25 and an adjusted VREF are used for landing with multiple hydraulic systems inoperative to improve flare authority, control response, and go-around capability. The aircraft may tend to float during the flare. Do not allow the aircraft to float. Fly the aircraft onto the runway at the recommended point.

Care should be exercised if the auto speedbrakes are used with hydraulic system 4 inoperative because only the outboard spoilers deploy. When only the outboard spoilers deploy, the rapid pitch up moment increases the possibility of a tail strike. This can be minimized by slowly extending speedbrakes manually and applying a positive forward elevator force.

If nose wheel steering is inoperative and any crosswind exists, consideration should be given to landing on a runway where braking action is reported at least as good or better. Braking action becomes the primary means of directional control below approximately 60 knots where the rudder becomes less effective. If controllability is satisfactory, taxi clear of the runway using differential thrust and brakes. If desired, the pilot may request a tug. Continued taxi with nose wheel steering inoperative is not recommended due to aircraft control difficulties and heat buildup in the brakes.

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.
- Apply steady, light braking when under approximately 500,000 pounds (227,000 kgs) and steady, light to moderate braking at higher weights.
- 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.

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
- 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.

Note: Extended taxi distances or fast taxi speeds can cause significant increases in temperatures on the remaining tires.

Gear Disagree

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.

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

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.

After landing, smoothly bring the aircraft to a complete stop. 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.

Note: Land in the center of the runway.

Use of Speedbrakes

During a partial gear landing, delay extending the speedbrakes until the nose and both sides of the aircraft have touched down. Extending the speedbrakes before this attitude can cause wing/nacelle scrape without wing gear, tail tip without body gear, or a hard landing without nose gear.

Use of Reverse Thrust

During a partial gear or gear up landing, the thrust reversers may not be available. With system 1 and 4 hydraulic pressure, at least one wing gear or one body gear on each side of the aircraft must be on the ground to satisfy the air/ground logic requirement for thrust reverser extension. If the air/ground logic requirement is met and the nose gear is partially extended or up, reverse thrust is still available. Without system 1 or 4 hydraulic pressure, the nose gear squat switch can satisfy the air/ground logic requirement for thrust reverser extension.

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Keep in mind that an engine making ground contact could suffer sufficient damage such that the thrust reverser mechanism may not operate. Selecting reverse thrust with any gear not extended may produce an additional asymmetric condition that makes directional control more difficult.

After Stop

Accomplish an evacuation, if needed.

Gear Disagree Combinations

Land in the center of the runway. After touchdown lower the nose gently before losing elevator effectiveness.

Nose Gear Only Extended

Use normal approach and flare attitudes maintaining back pressure on the control column until ground contact. The engines contact the ground prior to the nose gear

One Wing or One Body Gear Fails to Extend

Failure of one wing or one body gear to extend will not cause adverse impact on directional control during touchdown and landing rollout.

All Gear Up or Partially Extended

The engines contact the ground first. There is adequate rudder available to maintain directional control during the initial portion of the ground slide. Attempt to maintain the centerline while rudder control is available.

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 thrust levers 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 or FLCH 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 or FLCH may be re-selected.

Note: Any time VMO/MMO is exceeded, the maximum airspeed should be noted in the logbook.

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.

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 (if required)

The flight crew should don the oxygen mask 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 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.

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.

Wheel Well Fire

Prompt execution of the Wheel Well Fire NNC following a wheel well fire warning is important for timely gear extension. Landing gear speed limitations should be observed during this checklist.

Note: To avoid unintended deceleration below the new target airspeed, the autothrottle should remain engaged.

If airspeed is above 270 knots/.82 Mach, the airspeed must be reduced before extending the landing gear. Either of the following techniques results in the autothrottle reverting to the SPD mode and provides a more rapid speed reduction than using VNAV speed intervention or FLCH.

- Select altitude hold and set approximately 265 knots or less depending upon gross weight.
- Set the MCP altitude to a desired level-off altitude and use speed intervention to reduce airspeed.

Note: Additionally, the thrust levers may be reduced to idle and/or the speedbrakes may be used to expedite deceleration.

If the pitch mode is VNAV and the crew wishes to remain in that mode, select speed intervention to open the MCP command speed window and then set approximately 265 knots or less. If the pitch mode is FLCH and the crew wishes to remain in that mode, simply set approximately 265 knots or less. These techniques do not result in as rapid a speed reduction as reverting to the SPD mode, but allows the crew to remain in the pitch mode in use.

Windows

Window Damage

To do the Window Damage 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 both forward windows delaminate or forward vision is unsatisfactory, accomplish an ILS autoland, if available.

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.
- 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 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. Use caution when attempting to dampen pitch oscillations by use of engine thrust so that applications of thrust are timed correctly, and diverging pitch oscillations do not develop.
- 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.

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.

Fuel jettison should be a primary consideration if aircraft performance appears to be critical. In certain cases, this may also have a positive effect on lateral controllability.

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 (indicating a failure to automatically shutdown an asymmetric flap situation), 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.

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.

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.

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, and
- other factors dictated by the specific situation.

Human Factors
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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.

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.).

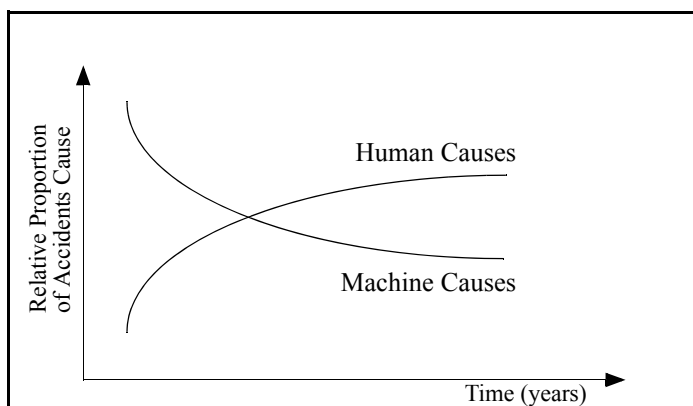
- Crew = pilots and flight attendants.
- Resource = people, skills, equipment, and services.
- Management = directing, controlling, and coordinating.

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)





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.

-
- **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.

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.

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 Pages. (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.

**747-400 Flight Crew Training Manual****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.



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 be 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.

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."

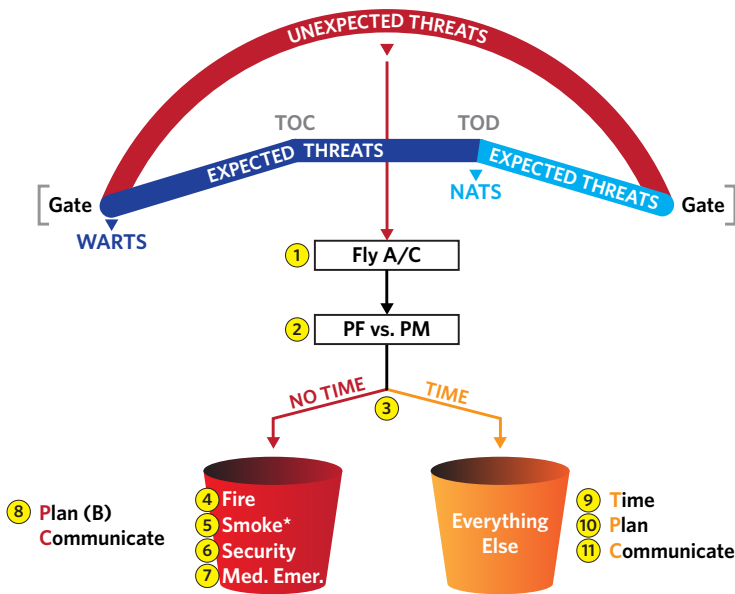
Note: It is not necessary to re-brief the plan to mitigate the highest threat if it was previously covered in WARTS or NATS.

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.

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.

Threat & Error Management Model



(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.)

(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.

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.

Selected References

Chapter 10

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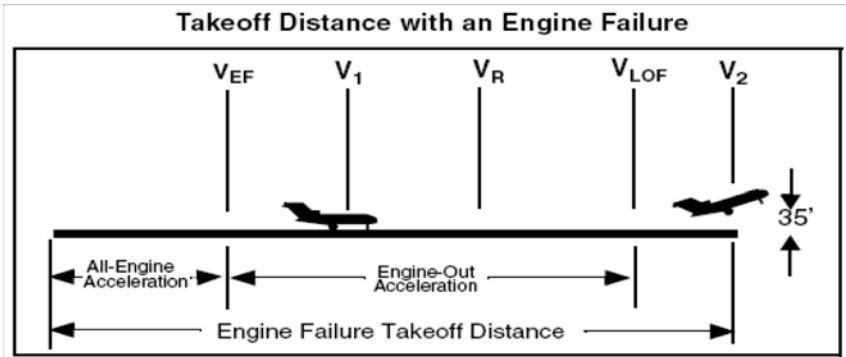
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Intentionally
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Engine Out

Engine Failure Takeoff Performance

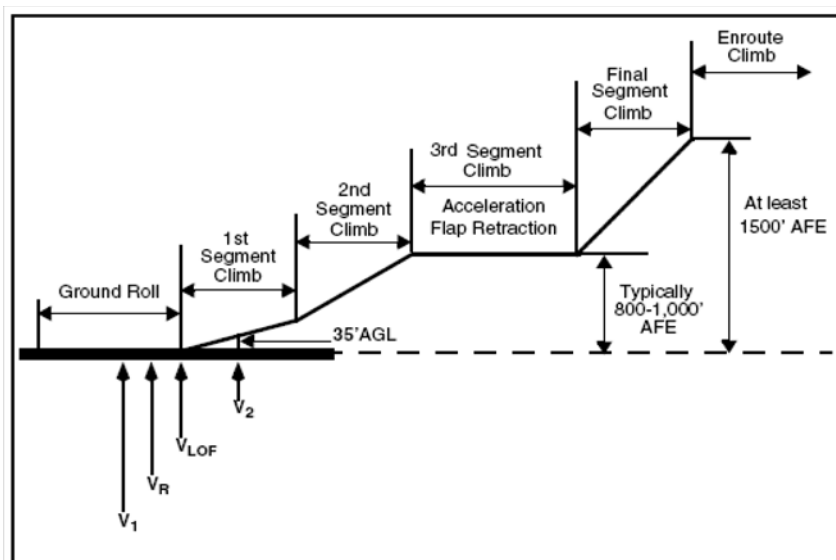
Engine failure takeoff distance is the distance from brake release to the point where the aircraft attains a height of 35 feet, assuming an engine fails at VEF. FAR 25 requires that the length of runway plus clearway be at least equal to the engine failure takeoff distance.



Takeoff 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 V_{LOF} 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 V_2 . 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.



Optimized V1

What does Optimized V1 mean?

V1 has been adjusted either faster or slower in order to increase the RATOW. This performance is part of the FAA certified aircraft takeoff performance for all airplanes in Delta's fleet except for the MD-88/90.

How is it possible to adjust V1 and still comply with the engine inoperative accelerate-stop and accelerate-go requirement from V1?

Optimized V1 is only useful when the RATOW is limited by factors other than the pure runway length, slope, and wind. It is used when the RATOW is limited by either:

- Obstacle Clearance: the performance capability to clear obstacles in the takeoff flight path with one engine inoperative, or
- Brake Energy: the performance capability of the brakes to absorb all of the energy generated by an accelerate-stop without melting.

When the RATOW is limited by obstacle clearance or brake energy, excess usable runway exists, i.e., the weight and the corresponding runway required are less than the actual runway length for a pure balanced field length case. Because the runway length used is less, the V1 can be adjusted and still comply with the accelerate-stop and accelerate-go requirement. The adjusted V1 can result in using all of the available actual runway length. The V1s are customized to the specific runway. (V1s from the ODM and the FMS are not.)

Why use Optimized V1?

RATOW is increased on obstacle or brake energy limited runways. Approximately 60% to 70% of our runways are obstacle limited, not balanced field length limited. Because of that, there is a tremendous opportunity to increase RATOWs.

How can the pilot tell when the WDR is using Optimized V1?

The WDR does not have the capability to indicate when the RATOW and V1 are based on Optimized V1. On airplanes that have FMS Vs speeds calculation capability, the WDR will display V1s that are different from the FMS. The WDR V1s should be used.

Shown below is an example using B767-400 pure performance (structural limits not withstanding) for ATL Runway 27R, which is obstacle limited.

OAT 65 deg F QNH 29.92 0 wind						
	Thrust/Flap	Climb Limit	RATOW	V1	VR	V2
Current Data:	PKOF TO/15	456168	444966	164	170	174
Optimized Vspeed Data:	PKOF TO/15	456168	450017	166	170	174
Balanced Field	PKOF TO/15	456168	456112	165	172	175
(no obstacles for comparison purposes)						

The relevant FAR takeoff performance runway distances for this comparison are:

	Runway Length	Accelerate- Go	Accelerate-Stop
Current Data:	11889	11349	11349
Optimized Vspeed Data:	11889	11153	11889
Balanced Field	118895	11889	11889
(no obstacles for comparison purposes)			

Improved Performance

This procedure is utilized at certain airports to optimize the takeoff V2 speed for improved takeoff weight capability. Standard takeoff speeds are set to provide good takeoff weight capability for a wide range of regular, non performance-critical airports. For some airports and runways, however, takeoff weight capability can be dramatically improved by selecting a different V2 speed that optimizes performance for the runway and elevation of interest. The technique of adjusting V2 up or down optimizes both runway and climb performance so that a maximum overall weight limit is obtained. V1 and Vr must also be modified to maintain consistent performance relationships.

The WDR will display “IMPF” on the runway analysis line when Improved Performance is being utilized, refer to FOM chapter 5.6.

In general, Improved Performance can only be used when there is no standing water, ice, slush or snow on the runway. If Improved Performance is the only available performance for a particular runway due to departure procedure requirements, however, contaminated runway performance will be available.



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 gradient 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.



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.



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.



- 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.



High Elevation Considerations

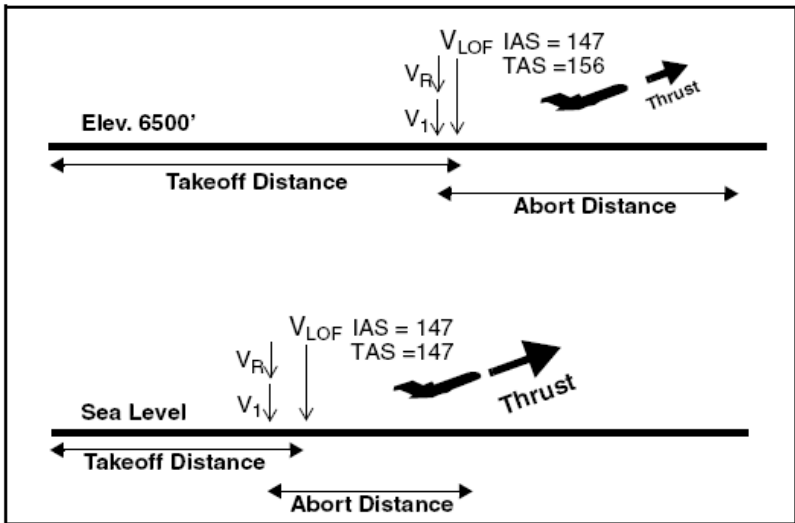
Aircraft Performance Characteristics

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.

Performance Comparison



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.

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: $KE = 1/2 MV^2$ 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.



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.



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.



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.



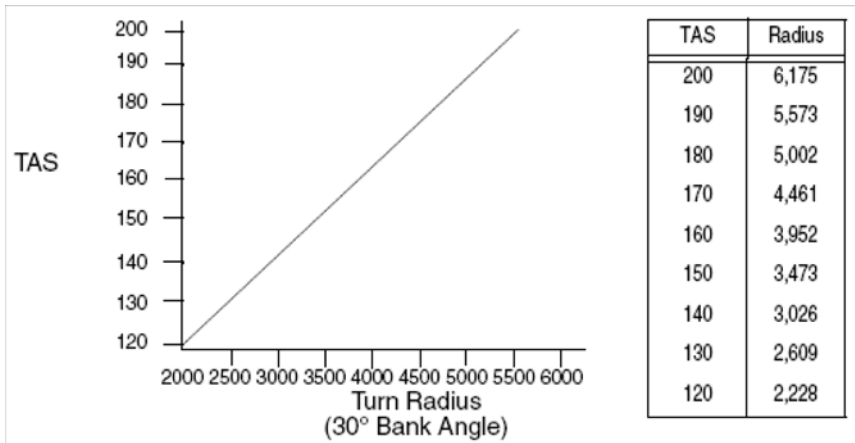
Turning Performance

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.





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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, $TAS/60 = \text{mpm}$. 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, $Mach \times 10 = \text{mpm}$, 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 $TAS/60 = \text{mpm}$ it is traveling at 3.5 mpm, radius (nm) = $\text{mpm} - 2$ (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

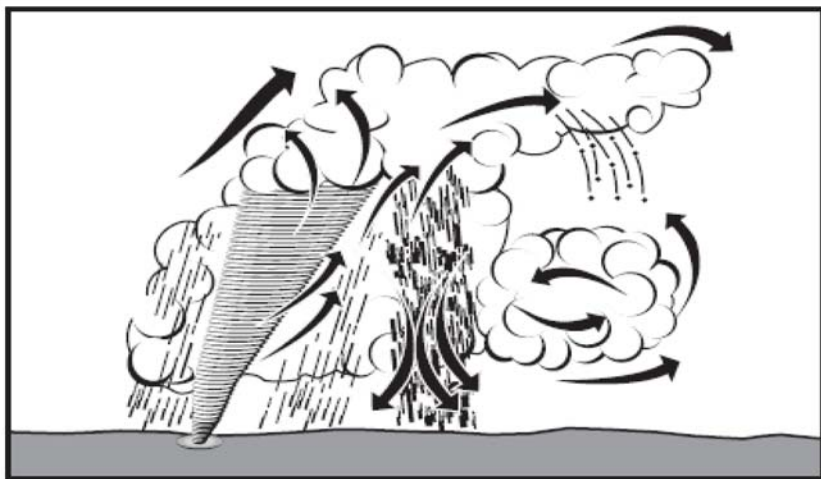
When a minimum radius turn is required or anticipated it is important to slow the aircraft. When the turn is initiated, use the maximum bank angle available. Winds cannot be ignored. Turns into the wind reduce turn radius in relation to terrain.

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

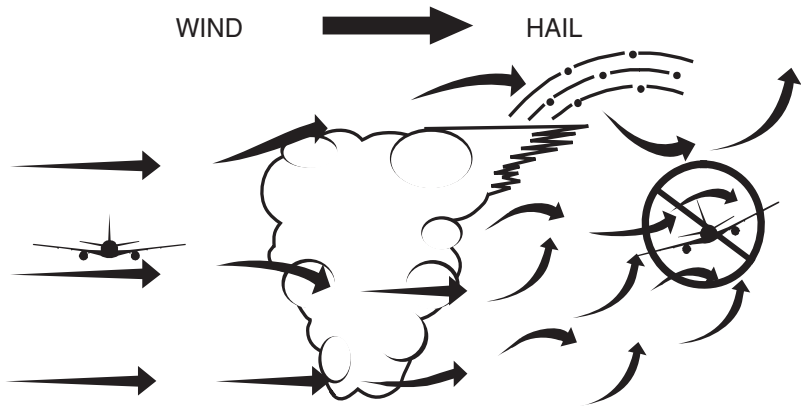
Turbulent activity occurs away from the heavy rain core. Enroute deviations should be made upwind of the storm whenever possible, especially if winds aloft are strong. Deviating downwind greatly increases the chance of encountering hail and turbulence. Turbulence can be expected to exist downwind of 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.



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.



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.

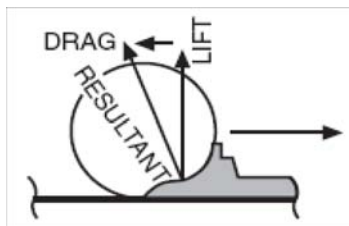
Experts generally agree that there are three types of hydroplaning: dynamic (or hydrodynamic), viscous, and steam (or reverted rubber). It is to be noted that these may be indistinguishable from the flight deck. All three types can seriously degrade the braking effectiveness and directional capability 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.

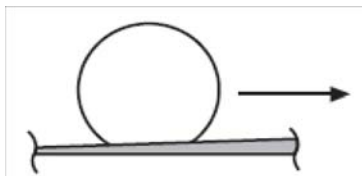
Additionally, as the tire accelerates, the center of hydrodynamic pressure shifts increasingly forward of the axle center line, creating a wheel spindown moment.

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.

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.



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.

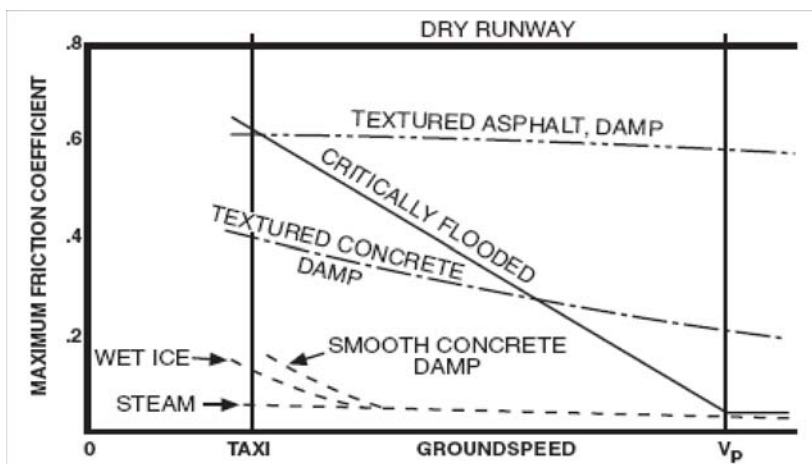
Steam Hydroplaning (Reverted Rubber)

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.



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 $V_p = 9$, 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.

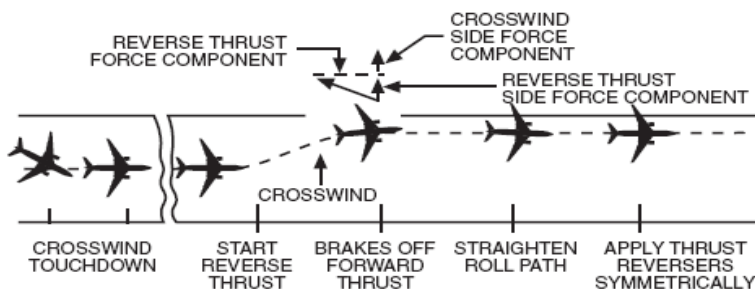
- Use minimum safe touchdown speed.
- Make early runway contact and early nosewheel contact to get maximum directional capability. A firm landing is better than a "grease job," which may induce hydroplaning in marginal conditions.

- 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.

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For maximum crosswind limits on a contaminated runway, refer to Vol. 1, SP.16, Adverse Weather.

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:

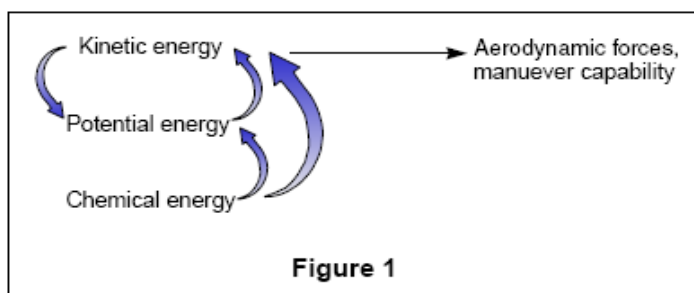
- Recognition to avoid or recognition to recover
- Protect from a stall
- Orient the lift vector
- Stabilize post recovery

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.



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).

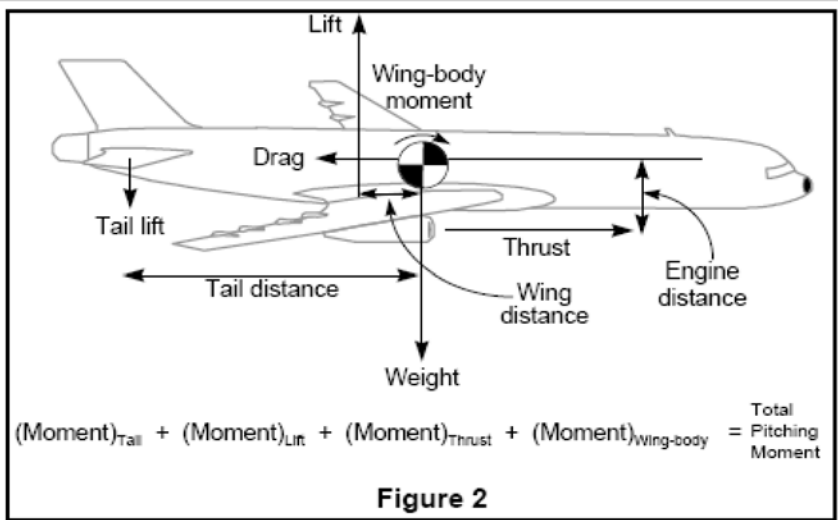
Only within these parameters will you be able to generate the aerodynamic forces necessary to maneuver an aircraft to return it to normal flight.



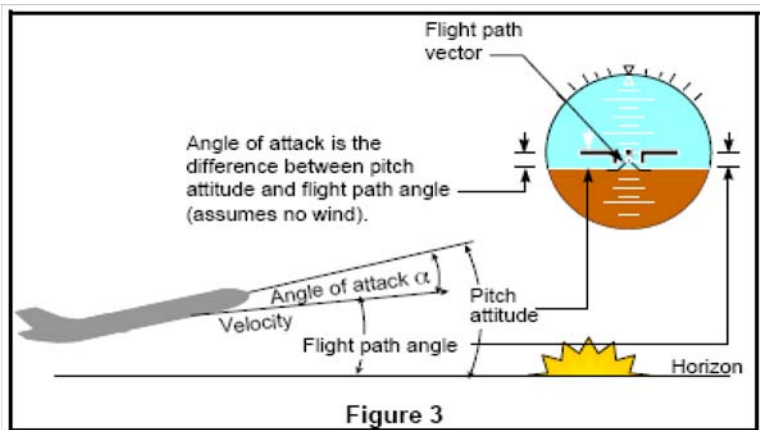
Flight Dynamics

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.



It is control of the flight path angle (or vector) that is critical to an aircraft during dynamic maneuver.



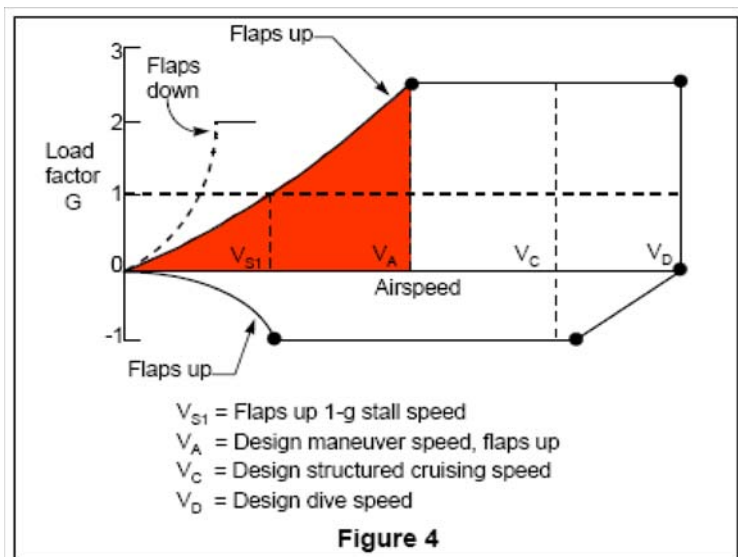
Load Factor

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.



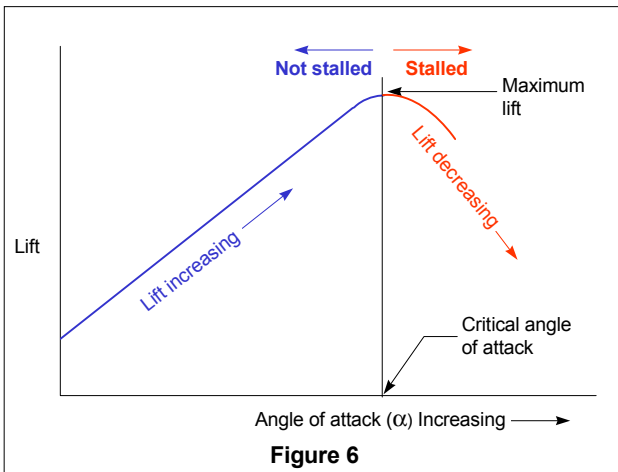
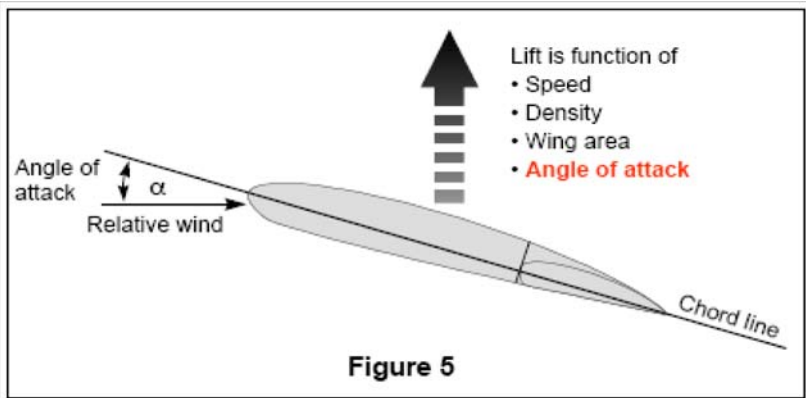
It is precisely in the shaded area along the 1G line that energy situational awareness must be most focused. Within this area of the flight envelope your recognition and response to an upset must be both timely and correct.



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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.



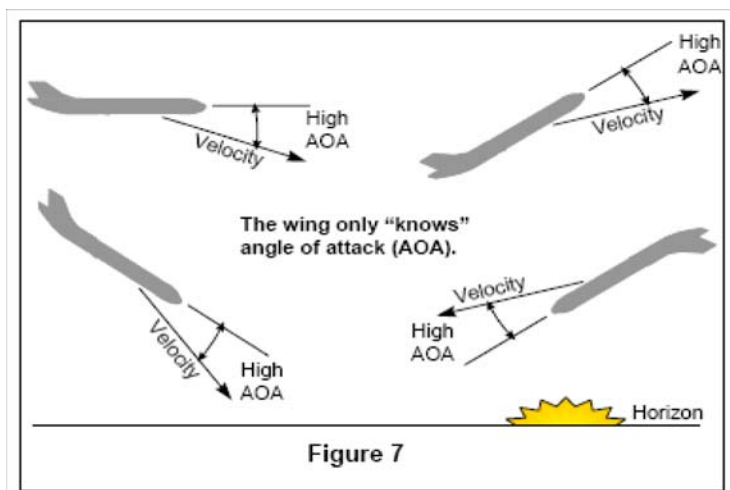
As indicated in the figure above, there is a linear increase in lift with increasing AOA up to the point of maximum lift. Beyond the critical AOA, lift decreases as the flow over the wing breaks down and the surface becomes stalled. It is the stalled condition which you must learn to recognize and recover from.

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.



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.



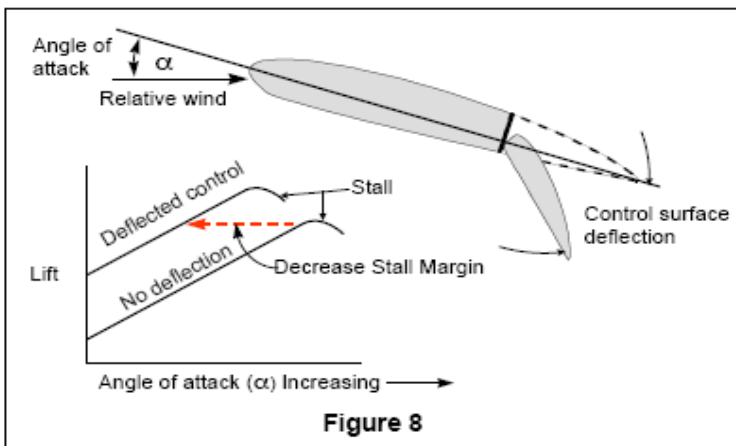
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Pilots should not expect the aircraft to remain unstalled just because the indicated airspeed is higher than AFM chart speeds because the conditions may be very different. In all cases, respect the stick shaker by unloading the aircraft (reduce AOA) if a stall is encountered.

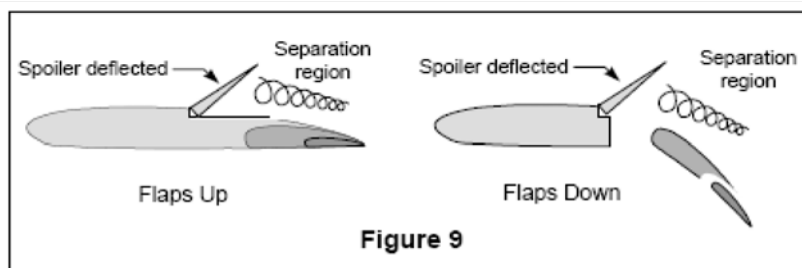
It is possible for an aircraft to be flown below the defined “stall speed.” In this low energy environment the trajectory will be largely ballistic and altitude will and must be traded to generate airspeed to produce sufficient lift for 1G flight. For this reason, at low airspeed it is important to reduce 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.



Note how the deflected aileron actually decreases the stall margin at high AOA 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.



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.

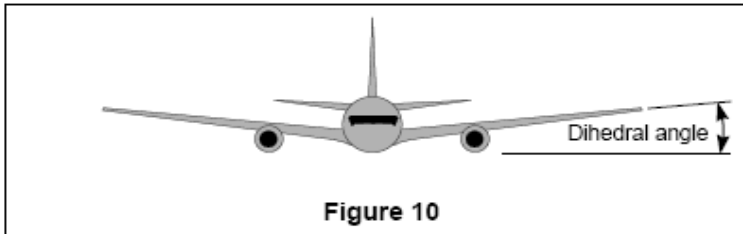


Figure 10

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.

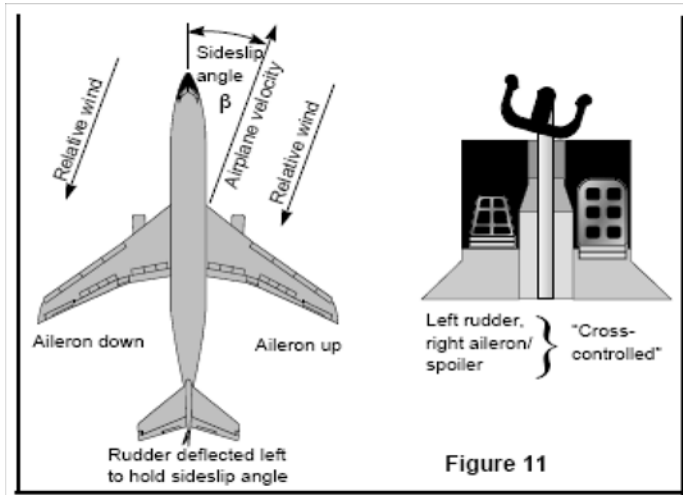


Figure 11

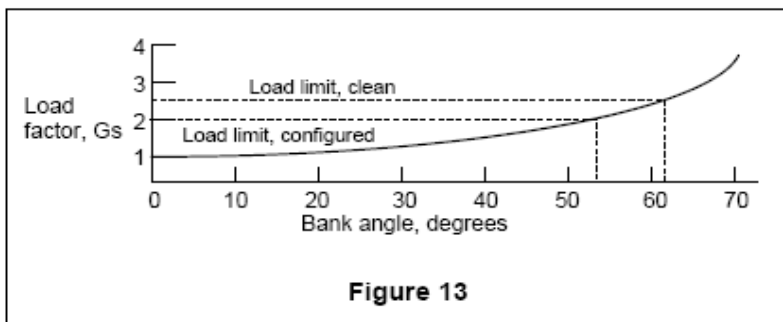
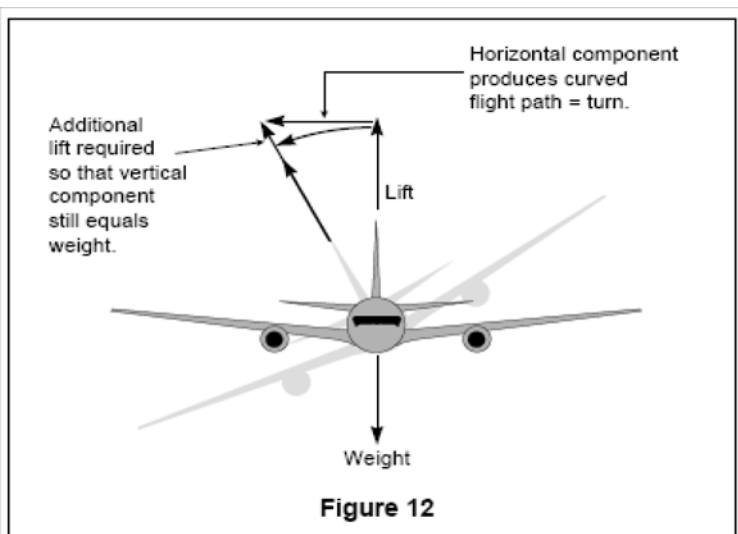
Sideslip can affect motion in all three axes, generating rolling as well as yawing motion. Roll coupling due to rudder induced sideslip is a common characteristic of swept wing aircraft with dihedral, especially at high AOA's and low energy states. Because of this, the rudder must be used with caution.



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.





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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.



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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