Lufthansa Flight Training (LFT) GmbH

(Preliminary Text)

Instrument Flight Procedures

Author: Wolf Scheuermann

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Contents

1 Introduction

This document is primarily intended for Lufthansa (LH) and Bundeswehr Luftwaffe (BW) instructor pilots and student pilots enrolled in flight training [1]. It describes the Instrument Flight Procedures (IFP) as performed with all Lufthansa training aircrafts and flight navigation procedure training devices (FNPT) and flight simulators. The procedures are also applicable in commercial flying, if neccessary.

The IFP described are based on the proposals of the International Civil Aviation Organization (ICAO) according to [2]. The procedures herein described comply with the requirement of the ICAO. That means an appropriate correction of the effects of the wind has to be applied.

The purpose of the IFP is to enable manual flying of an aircraft under instrument flight rules (IFR) up to and including CAT I precision approaches. Conventional instrument flying as well as area navigation (RNAV) is covered.

No description of automated procedure flying as performed by track keeping, autopilot or flight management systems is given.

1.1 Principles

The design of the IFP is guided by three basic principles:

1. An IFP shall be independend of the particular navigation aid in use and the used indication or display of the navigational onboard system. Exceptions may exist.
2. An IFP shall be independend of the aircraft (A/C) type size and speed: Therefore time distance, i.e. flight time, instead of ground distance should be used. If the aircraft's performance matters, the IFP mention the aircraft categories.
3. Two kinds of Wind Corrections are usually applied to the outbound courses, consisting of:
   (a) Heading (HDG) correction
   (b) Time correction

The IFP usually can effortlessly be performed using "techniques", easily memorizable rules or procedures, without the need to calculate formulas. Examples are the techniques "*Charlie Brown*" and "*Tom Cat*" for determining the interception heading inbound and outbound, respectively. The student pilots are requested to ask their instructor pilots for such techniques.

The focus of this document is upon the student pilot who is not familiar with manual instrument flying. Nevertheless, this document does not yet contain

- examples
- pictures
- chart legends
- exercises
- etc

but it always gives notes, remarks, hints, warnings, etc where neccessary.

Note: *Due to the heavy use of rules of thumb, in IFP there exists usually not one "master solution" but always an interval of solutions that fits the desired skills to fly manually!*

1.2 Disclaimer

Texts, pictures, tables, etc are not quoted as far as they are taken from the ICAO document [2]. Other sources are quoted properly.

Navigational charts, maps, plans, tables, etc as reproduced herein are outdated, not valid, and must not be used for navigation. Only the valid and up-to-date version of the according document must be used in flight operations.

Errors may be burdened upon the author but he can not give any guarantee and can not take responsibility for the relevance, the completeness, and correctness, or for the use of this document by LH. This responsibility remains solely with the team leaders, the project leaders, the CEO, the LFT GmbH, and LH.

1.3 Acknowledgments

The author wants to express his thanks to Günter Kellner for his critical support and useful corrections, also the flight instructors of the 4th Flying Squadron of the LTG 62 "Hans Huckebein" of the German Airforce for their feedback

Note: *Remarks of the LFT instructor pilots did not yet arrive.*

2 IFR Charts

For planning purposes and every flight under IFR the following navigational charts are used in a given sequence:

1. Departure airport or aerodrome charts
2. Standard Instrument Departure charts (SID)
3. Enroute or airway charts (LH: Radio Facility Charts (RFC))
4. Standard Arrival Route chart (STAR)
5. Instrument Approach and Landing charts (IAC)
6. Destination airport or aerodrome charts
7. Alternate airport or aerodrome charts
8. Supplemental charts

For detailed information see the respective chart legends [3] [5]. The visual depiction of waypoints, course lines, headings, etc in the charts are based on textual descriptions of the procedures and desired flight paths. These descriptions are often given for SID and STAR as additional text information and coordinate lists.

Note: *Except if instructed by Air Traffic Control (ATC) or in case of emergency no other procedures are allowed than those depicted in the charts. Adherence to chart information is required in case of communication failure.*

2.1 Airport or Aerodrome Charts

Airport or Aerodrome (A/D) Charts contain descriptions of the airports, aerodromes, airfields, and its facilities, the layout of the parking positions, taxi ways, runways, etc. It also contains sometimes take off minima and alternate minima if the field is used as an alternate. There may exist many A/P charts for an aerodrome, especially for larger airports.

2.2 Standard Instrument Departure Charts

Standard Instrument Departure (SID) Charts describe the routes, headings, altitudes, fixes, distances, etc to leave the runways of an airfield and how to proceed to the airways. More than one SID may exist for an airport.

Note: *Very often the SID charts are not to scale!*

2.3 Enroute or Airway Charts

Enroute or Airway Charts describe the airways. They contain fix points (enroute fixes), course lines, radio aids, distances, courses, different types of minimum safe altitudes (MSA), Minimum Grid Altitudes (MGA), and especially Minimum Enroute Altitudes (MEA)) limits, boundaries, route designators, etc of which airways consist. Airway charts are drawn to scale. An enroute chart may contain further features like coast lines, river, airports, frequencies, for information.

Note: *LH calls these charts Radio Facility Charts (RFC)!*

2.4 Standard Arrival Route Charts

Standard Arrival Route (STAR) Charts describe the routes and information how to leave airways and approach the initial approach fixes (IAF) of an aerodrome. The last MEA before arriving at the IAF is called Initial Approach Altitude (IAA). More than one STAR may exist.

Note: *Very often the STAR charts are not to scale!*
Note: *In manual flying the IAF is a fly-over waypoint.*

Instrument Approach and Landing Charts

For every runway of an airport may exist one or more published approach procedures, depending on the available navigational aids. Every approach is published in an Instrument Approach and Landing Chart (IAC).

These charts give information in textual, tabulatory, and mapped form (lateral plan, vertical profile section) about approach segments, procedure turns, the vertical profile, the missed approach procedure, altitudes, distances, frequencies, limits, the Minimum Descend Altitude (MDA) in case of a non-precision approach or the Decision Altitude (DA) in case of a precision approach or a continuous descend approach, the Visibility (VIS), the Runway Visual Range (RVR), the Minimum Sector Altitude (MSA), navigational aids, IAF, Intermediate approach Fix (IF), Final Approach Fix or Point (FAF/FAP), the Missed Approach Point (MAP) in case of a non-precision approach, the missed approach fix (the holding fix at the end of the missed approach), etc of the respective approach.

The plan is to scale except for insets. The vertical profile is overscaled.

2.5 Supplemental Charts

Supplemental Charts may contain additional information like boundaries of air traffic services, bird routes, radar vector altitudes, etc.

2.6 Summary: IFR Charts

Phase of Flight	IFR Chart
Taxi and Take Off	Departure Airport Chart
Departure	Standard Instrument Departure Chart (SID)
Enroute	Enroute or Airway or Radio Facility Chart (RFC)
Arrival	Standard Arrival Route Chart (STAR)
Approach	Instrument Approach and Landing Chart (IAC)
Taxi and Parking	Destination Airport Chart
Other	Supplemental Charts

Table 1: IFR Charts

2.7 Summary: Sections of an IFR Flight

Route	Begin	End
SID	Runway	Enroute Fix
Airway	Enroute Fix	Enroute Fix
STAR	Enroute Fix	IAF
IAC	IAF	MAP, DA, or Runway
Missed Approach	MAP, DA	Missed Approach Fix

Table 2: Sections of an IFR Flight

3 Instrument Flight Procedures

The following sections describe the IFP as may be used by LH and BW.

The first three sections describe **Basic Procedures**. All other procedures make use of these basic procedures, or are sequences, or combinations of these procedures.
The fourth section desribes **Interceptions** and the fifth section describes the procedures to be performed for **Holdings** and **Racetrack Patterns**.

3.1 Flying Straight and Level

This section describes the two procedures to fly straight by means of instruments. The emergency procedure "Homing" is not described.

Note: *The reference direction for bearings, headings, courses, tracks or any other azimuthal angle may be true north, magnetic north, compass north, or any other north reference direction. Without restrictions magnetic north is used throughout this document.*

Note: *During a straight flight, the Altitude (ALT), or Flight Level (FL) is usually maintained. Complex procedures may allow climbing or descending during straight flight.*

3.1.1 Heading

In some instances flying a given Heading (HDG) is required. This HDG is flown as instructed. A wind correction is never applied!

Note: *So-called "Radar Vectors" as ordered by ATC consist usually of HDG, and, may be, ALT or FL and Speed (SPD) to fly.*

3.1.2 Tracking

Tracking a course line to a station, or from a station, or tracking from one waypoint to another, is flying onto the course line and adjusting the track (TRK) to the course (CRS).

An aircraft is on the course line if it is located in the ***Safe Sector*** and tracking or intercepting the course line. The Safe Sector extends from centered to ±half scale deflection (HSD) of the course deviation bar on a Horizontal Situation Indicator (HSI) or a Course Deviation Indicator (CDI). If a Radio Magnetic Indicator (RMI) is used, the Safe Sector extends $\pm 5^o$ off the MC. Due to measurement errors it is required to maintain zero deflection as close as possible.

Once on track this is achieved by applying the correct Wind Correction Angle (WCA) to the course (here MC) to compensate for the Expected Drift (D_e) and to get the heading (MH):

$$MH = MC + WCA$$

In case advanced navigation systems and indicators are used the displayed Drift Angle (DA) is used to adjust the TRK to the CRS:

$$MT = MC \quad if \quad MH = MC - DA$$

So the HDG fits the CRS and the track line fits the course line if the Cross Track Error (XTK) is zero.

Note: *There exist techniques for tracking without the neccessity to calculate.*

3.2 Climb and Descend

This section describes climb and descend procedures.

Note: *Climb and descend occur usually during straight flight but can also appear in turns.*

3.2.1 Climb

The climb performance depends on the aircraft, therefore many procedures are in use.

Climb with ...

...constant Indicated Air Speed (IAS) with particular power setting

...constant Mach number (M) with particular power setting

...constant Rate of Climb (RoC)

...constant pitch angle

...constant Angle of Attack (AoA)

...etc

Note: *Refer to your Aircraft Operation Manual (AOM, OM-B) for the correct procedure.*

Top of Climb

The Top of Climb (TOC) is the point where the new ALT or FL is reached after climbing.

The distance to the TOC is calculated using $\triangle ALT$, the height to climb, the average Rate of Climb (RoC), and the average Ground Speed (GS) in climb

$$d_{TOC[NM]} = av.GS_{Climb[kt]} \cdot t_{Climb[h]} = av.GS_{Climb[kt]} \cdot \frac{\triangle ALT_{[ft]}}{60 \cdot av.RoC_{[fpm]}}$$

where the Climb Time (t_{Climb}) is

$$t_{Climb[min]} = \frac{\triangle ALT_{[ft]}}{av.RoC_{[fpm]}}$$

Note: *There is a variety of procedure to determine the TOC, depending mainly on the performance documentation available for the specific A/C. Refer to your Aircraft Operation Manual (AOM, OM-B) for the correct calculation.*

3.2.2 Descend

Every powered aircraft is able to maintain a glide path with a Glide Path Angle (GP) of about 3^o.

Rate of Descend

For a 3^o GP the Rate of Descend (RoD) depends on the Ground Speed (GS). It is calculated according to

$$RoD_{[fpm]} \approx 5 \cdot GS_{[kt]}$$

Note: *The numerical factor is approximately* $100 \cdot tan(GP)$*, also called the glide path* ***Gradient****. If the glide path angle doubles the numerical factor approximately also doubles.*

Note: *To adjust the rule of thumb, add or subtract 1 to the numerical factor if the glide slope increases or decreases ca* $\frac{1}{2}^o$*, respectively. Or: The numerical factor changes ca* $\frac{2}{10}$ *per* 0.1^o *glide slope change.*

Top of Descend

The Top Of Descend (TOD) is the point where the present ALT or FL is left and the descend is commenced.

The **Bottom of Descend** (BOD) is the last ALT or FL before reaching the aiming point of the descend. The aiming point may be the touch-down zone on the RWY. Here the BOD ist the Touch-Down Zone Elevation (TDZE). Or it may be the last MEA before arriving at the IAF, the so-called Initial Approach Altitude (IAA). The BOD also may be any ALT at a given Waypoint (WP).

The distance from TOD to Bottom of Descend is approximately

$$d_{TOD[NM]} \approx \frac{\Delta ALT_{[ft]}}{1000} \cdot 3 \approx \frac{\Delta FL_{[100ft]}}{3}$$

Note: *This can also be used to determine the distance of the Visual Descend Point (VDP) from the touch down zone.*

If descending from cruising ALT or FL to the IAA, add 5 NM to d_{TOD}.

3.3 Turns

All turns under IFR are performed with the so-called Standard Rate Turn (SRT).

Note: *During a turn, ALT, or FL, is usually maintained. Complex procedures may allow climb or descend during turns.*

3.3.1 Standard Rate Turn

In a SRT the Rate of Turn (RoT) is per definition performed with an angular velocity of 3^o per second. Thus, it takes 2 minutes to perform a 360^o full circle ("Three Sixty"), or, to put it the other way, the circumference of a SRT is two minutes time distance.

Note: *These definition can be applied to fly a SRT in case of emergency with a partial instrument panel.*

The radius of the SRT is 20 seconds time distance.

3.3.2 Bank Angle

In a coordinated turn the Bank Angle β is a funktion of the TAS. The bank angle is limited by the structural, and aerodynamical limits of the aircraft, and passenger comfort limits.

In a SRT the bank angle is approximated by

$$\beta \approx \frac{TAS}{10} + 7 \, [^o]$$

Note: *This formula is best suited for TAS $\geq$ 150 kt and used by LH. LH limits the maximum β to 25^o or 30^o.*

Another formula is

$$\beta \approx \frac{TAS}{10} \cdot 1.5 \, [^o]$$

Note: *This formula is best suited for TAS $\leq$ 150 kt. In the TAS range from 100 kt to 200 kt where most procedures are flown both formulas deliver approximately the same bank angle.*

There might be cases where a wider turn than SRT is needed. These turns are performed with half the bank angle of SRT.

Summary: Basic Procedures

Basic Procedures

Procedure	Action
Flying straight	Adjust MH and TRK to CRS
Turn	Adjust RoT, bank angle, TAS
Climb	Adjust RoC according to AOM
Descend	Adjust RoD to GS and GP

Table 3: Basic Procedures

3.4 Interceptions

If an aircraft shall track a course line but is not within the safe sector an interception procedure has to be performed. Interception is the task of finding the HDG to close in on the desired course line.

Note: *No WCA has to be applied during interception!*

Depending on the A/C position relative to the station two kinds of interception exist:

1. interception inbound to station (waypoint)
2. interception outbound (from station)

The angle between the Interception HDG (MH_{INT}) and the Desired CRS ($MC_{Desired}$) is called the Interception Angle (i)

$$i = MH_{INT} - MC_{Desired}$$

Note: *The maximum allowable interception angle is* 90^o *if the aircraft is far from the desired course line. The minimum is* 30^o *if the aircraft is already in the vicinity of the desired course line.*

The angle between the actual bearing and the desired bearing to or from the station, respectively, is the required Bearing Change (G)

$$G = MB_{actual} - MC_{Desired}$$

Note: *Due to the maximum interception angle* $i_{max} = 90^o$ *the procedure applies up to a maximum bearing change of* $G_{max} = 60^o$*. In the case of* $G > 60^o$ *a different interception procedure is used.*

3.4.1 Interceptions Inbound

The Interception HDG inbound (MH_{INT}) is calculated according to

$$MH_{INT} = MC_{Desired} \pm (G + 30^o)$$

where the adaptive interception angle becomes

$$i = G + 30^o$$

and the bearing change is

$$G = MB_{To} - MC_{Desired}$$

Note: *The formula for the calculation of the interception HDG is ambiguous and therefore not well suited for the use in the aircraft.*

Note: *There exist lots of techniques to find the interception headings without calculation.*

3.4.2 Interceptions Outbound

For interception outbound LH uses also an adaptive i in the formula for the interception HDG.

LH Interception HDG outbound:

$$MH_{INT} = MC_{Desired} \pm (G + 30^o)$$

The bearing change is

$$G = MB_{From} - MC_{Desired}$$

and the interception angle is

$$i = G + 30^o$$

BW uses a slightly different (and easier) procedure with a constant $i = 45^o$:

BW Interception HDG outbound:

$$MH_{INT} = MC_{Desired} \pm 45^o$$

Note: *LH should adopt the BW procedure for interceptions outbound!*

3.4.3 Angle of Lead

When intercepting a desired course line at an interception angle of 90^o an Angle of Lead (AoL) is applied to avoid overshooting or undershooting the course line. The AoL is the angle between the point where to start the SRT to intercept the course line, the station, and the interception point on the desired course line.

Given the Time Distance (t_D) from the interception point to the station the AoL is calculated according to

$$AoL_{\perp[^o]} \approx \frac{20}{t_{D[min]}}$$

In the case that the DME-distance from the interception point to the station is known the AoL is calculated as follows

$$AoL_{\perp[^o]} \approx \frac{TAS_{[kt]}}{3} : DME_{[NM]}$$

Note: *Because rarely the above mentioned DME distance is known it is allowable to use the current DME distance when the interception order is received, as an approximation. Also, because of the usually unknown GS the TAS is used, as an approximation.*

The AoL is usually a small angle. The following rules apply:

AoL with Interception Angle greater 45^o

In case of $i > 45^o$ the $AoL_\perp$ is applied.

No AoL with Interception Angle 45^o or less

If $i \leq 45^o$, no AoL at all is applied. This is the case when the aircraft is already close to the desired course line.

Note: *LH intercepts in such cases with $i = 30^o$, BW applies $i = 45^o$.*

3.4.4 Interceptions with $G > 60^o$

If the bearing change is greater than 60^o the following procedure applies for interception inbound as well as for interception outbound:

- Fly for two minutes parallel to the desired CRS in opposite direction.
- Start the timer when abeam to the course line from the station, or ...
- ... start the timer immediately if $90^o \geq G \geq 60^o$.
- After the time elapsed turn perpendicular towards the course line on

$$MH_\perp = MC_{Desired} \pm 90^o$$

- At $AoL = 10^o$ start turning to $MC_{Desired}$.
- Adjust MH for tracking $MC_{Desired}$.

Note: *This interception procedure fits interception inbound as well as interception outbound.*

Summary: Interceptions

1. Interpret the interception order and determine the $MC_{Desired}$.
2. Find MH_{Int}.
3. Turn to the MH_{Int}.
4. Fly the MH_{Int} until reaching the AoL or the safe sector.
5. Turn to the MH to track the $MC_{Desired}$.

3.5 Holdings

Sometimes it is neccessary to wait inflight over a given position (Holding Fix). Other than a helicopter an aeroplane is not able to hover.

In manual instrument flight it is not possible to apply wind corrections while turning. Therefore holding patterns are designed to allow proper wind corrections while 'circling' overhead the holding fix.

Note: *In a holding pattern a student pilot is challenged to show all his flying skills in a few minutes. So flying holding patterns is popular in flight training. During commercial flights they are considered a waste of time and are to be avoided.*

Holding Pattern Design

A holding pattern consists of

- a Holding Fix, the position where to wait. In manual flying the holding fix is a fly-over waypoint.
- an Inbound Leg, a course line leading to the holding fix and ending there. On the inbound leg tracking is mandatory.
- a Holding Side, the side of the inbound leg where the turns have to be performed.
- a Non-Holding Side, the side of the inbound leg where the airplane must not turn.
- an Outbound Turn, also called Fix End, a SRT leading onto the holding side, beginning at the holding fix, and ending at the begin of the outbound leg.
- an Outbound Leg, a course line leading parallel outbound to the inbound leg over a defined (time-)distance. In manual flight the outbound leg lacks instrument guidance.
- an Inbound Turn, also called Outbound End, a SRT beginning at the end of the outbound leg and ending on the inbound
- (sometimes) an Secondary Holding Fix, at the end of the outbound leg.

Published holding patterns are displayed on charts where the type of pattern is symbolized, together with the inbound course (CRS_{inbd}), and the Minimum Holding Altitude (MHA), and, maybe, speed restrictions. Non-published holdings may be ordered by ATC or the IP, where at least the holding fix, the (CRS_{inbd}), and the MHA has to be given.

There exist two general types of holding patterns, beside other distinctions:

- Right-Hand Pattern, (earlier called Standard Pattern), and
- Left-Hand Pattern, (earlier called Non-Standard Pattern)

Note: *When a non-published holding is ordered and no turn direction is given it is always a right-hand (standard) pattern. Otherwise, for a left-hand pattern the turn direction has explicitely to be ordered.*

Wind Corrections

Generally, in procedures wind corrections for turns and legs are applied on legs, which, due to the lack of instrument guidance, cannot be tracked. Therefore, in a holding pattern the wind corrections for the outbound and inbound turns and the outbound leg are applied to the outbound leg.

The overall goal is to hit the point of interception of the inbound leg as close as possible.

HDG Corrections

Principle: As many unguided turns and course lines of one minute length are found in a procedure, so many times the $WCA_{outbound}$ is applied to the outbound CRS.

Modifications exist:

1. For an outbound leg of one minute time distance length:

$$MH_{outbound} = MC_{outbound} + 3 \cdot WCA_{outbound}$$

2. For an outbound leg of 1.5 minute time distance length:

$$MH_{outbound} = MC_{outbound} + 2 \cdot WCA_{outbound}$$

3. For an outbound leg of time distance length greater than 1.5 minute and outbound legs with given distance length: for 1.5 minutes

$$MH_{outbound} = MC_{outbound} + 2 \cdot WCA_{outbound}$$

then

$$MH_{outbound} = MC_{outbound} + 1 \cdot WCA_{outbound}$$

Time Corrections

The Time Correction for a course line of one minute time distance is taken from the following table. The time correction depends on the actual Wind Speed (V) and the Wind Angle (wa):

Corrections for 1 min Time Distance

Wind Angle	**Headwind**	**Tailwind**
$0^o \leq wa \leq 30^o$	$+1.5 \cdot$V in sec	$-1 \cdot$V in sec
$30^o < wa \leq 60^o$	$+1 \cdot$V in sec	$-1 \cdot$V in sec
$60^o < wa \leq 90^o$	0 sec	0 sec

Table 4: One Minute Time Corrections

The Time Correction for a course line of 1.5 minute time distance is calculated according to the following table:

Corrections for 1.5 min Time Distance		
Wind Angle	**Headwind**	**Tailwind**
$0^o \leq wa \leq 30^o$	$+2\cdot$V in sec	$-1.5\cdot$V in sec
$30^o < wa \leq 60^o$	$+1\cdot$V in sec	$-1\cdot$V in sec
$60^o < wa \leq 90^o$	0 sec	0 sec

Table 5: One and a Half Minute Time Corrections

Time corrections for longer time distances are composed with due diligence from both tables.

Note: *Therefore also the One and a Half Minute Time Corrections table can be deleted.*

3.5.1 Holding Entry Procedures

The purpose of the holding entry procedures is to help the pilot to align easily with the inbound leg while approaching the holding fix from different directions.

The ICAO defines three sectors with different types of entry procedures. LH uses one more entry sector.

Sector Boundaries

1. The first sector boundary is the extension of the inbound leg to the opposite side of the holding fix.
2. The second sector boundary is a line 70^o off the inbound leg from the holding fix to the holding side.
3. The third sector boundary is the extension of the second sector boundary from the holding fix to the non-holding side.

Note: *There exists a **Zone of Flexibility** (ZofF - to avoid the said) of* $\pm 5^o$ *off every sector boundary where the pilot can choose the entry procedure to his discretion.*

Entry Sectors

Sector I is located between the first and the second sector boundary. It is also called the Parallel Entry Sector.

Sector II is located between the first and the third sector boundary. It is also called the Teardrop (or Offset) Entry Sector.

Sector III is located between the second and the third sector boundary. It is also called the Direct Entry Sector.

Sector IV (Lufthansa) is located within Sector III and extends 40^o off the third sector boundary. It is also called the Special Direct Entry Sector.

Sector I Entry: Parallel Entry

The parallel entry procedure is performed as follows:

1. After passing overhead the holding fix turn to

$$MH_{parallel\ outbound} = MC_{outbound} + 2 \cdot WCA_{outbound}$$

2. Fly $MH_{parallel\ outbound}$ for 1 minute + time correction according to the 1min table.
3. Start timer when on $MH_{parallel\ outbound}$.
4. After time elapsed turn opposite to the inbound turn towards the holding side.
5. Intercept $MC_{inbound}$ with an interception angle of 45^o, or track direct to the holding fix..
6. Track the inbound course with $MH_{inbound} = MC_{inbound} + WCA_{inbound}$.

The parallel entry procedure ends with the second passage overhead the holding fix.

Sector II Entry: Teardrop Entry

The teardrop entry procedure is performed as follows:

1. After passing overhead the holding fix turn to

$$MC_{teardrop} = MC_{outbound} \pm 30^o$$

according to the holding side.

2. Calculate $MH_{teardrop}$ according to

$$MH_{teardrop} = MC_{teardrop} + 2 \cdot WCA_{teardrop}$$

where $WCA_{teardrop}$ is the wind correction angle for the teardrop course.

3. Fly $MH_{teardrop}$ for 1 minute + time correction according to the 1min table and in relation to $MC_{teardrop}$.
4. Start timer when overhead holding fix.
5. After time elapsed commence the inbound turn towards inbound course.
6. Track the inbound course with $MH_{inbound} = MC_{inbound} + WCA_{inbound}$.

The teardrop entry procedure ends with the second passage overhead the holding fix.

Sector III Entry: Direct Entry

The direct entry procedure ends with the first passage overhead the holding fix.

Sector IV (Lufthansa) Entry: Special Direct Entry

The special direct entry procedure is performed as follows:

1. After passing overhead the holding fix start timer.
2. Fly for 20 seconds
$$MH_{\perp} = MC_{outbound} \pm 90^o$$
according to the holding side.
3. After time elapsed turn to
$$MH_{outbound} = MC_{outbound} + 3 \cdot WCA_{outbound}$$
4. Fly $MH_{outbound}$ until timer indicates 90 seconds + time correction according to the 1min table and in relation to $MC_{outbound}$.
5. After time elapsed commence the inbound turn towards inbound course.
6. Track the inbound course with $MH_{inbound} = MC_{inbound} + WCA_{inbound}$.

The special direct entry procedure ends with the second passage overhead the holding fix.

3.5.2 Checks

In some cases checks of the initially calculated outbound heading and timing can be performed:

HDG Check

The HDG Check reveals if the HDG correction on the outbound leg was sufficient. This so called 15^o-Check is performed as follows:

1. Calculate, without any wind correction, the LOP from the holding fix to the vertex of the inbound turn. This LOP has an offset angle α of 15^o off the $MC_{inbound}$.
2. Passing the vertex of the inbound turn, the $MH_{\perp}$ is orthogonal to $MC_{inbound}$.
3. Check if $MH_{\perp}$ is reached at the 15^o offset LOP.
4. If not, adjust the pattern $MH_{outbound}$ accordingly.

This check has two different consequences:

1. **Immediate action:** It indicates if overshooting or undershooting the $MC_{inbound}$ is imminent. Proper action has to be taken immediately by increasing the RoT or by breaking the turn and intercepting the $MC_{inbound}$.

2. **Adjustment of the correction:** An overshooting or undershooting indicates a not adequate HDG correction of the $MH_{outbound}$, depending on the wind situation and the kind of pattern. Proper adjustments have to be made.

Note: *Ask your flight instructor for proper adjustment techniques to compensate for the deviations.*

Note: *The 15^o-check is not possible while using an ADF-RMI due to the dip error! Instead the A/C should be located on the 30^o-offset QDR when the outbound time has elapsed.*

Time Check

In case of a Time Pattern the time correction on the outbound leg is checked by measuring the time distance of the inbound leg.

1. When inbound on the inbound leg in the safe sector start the timer.
2. Stop the timer when overhead the holding fix.
3. Read the measurement of the inbound time and compare it to the nominal pattern time.
4. If a time difference is measured the time correction on the outbound leg has to be adjusted properly.

Note: *Ask your flight instructor for proper adjustment techniques according to the measured time difference.*

3.5.3 Holding Types

Variants of the holding patterns are:

- time patterns,
- distance patterns,
- special patterns.

Time Patterns

Besides the 1 min time pattern there exist 1.5 min time patterns, 2 min time patterns, 3 min time patterns, and may be even longer time patterns. In every case the length of the inbound leg is the specified time, regardless of the wind situation.

While the inbound leg is tracked, the outbound leg is flown according to the outbound heading and time corrections.

Checks must be adjusted to the time distance of the inbound leg:
Here, the offset angle α of the LOP for the HDG check may be calculated using

$$\alpha_{[^o]} \approx \frac{15}{t_{inbound}[min]}$$

The time check tests the time distance of the inbound leg.

Note: *During training, check flights, and in written exams only the procedure of the 1 min time pattern is used.*

Distance Patterns

In Distance Patterns the end of the outbound leg is determined by the slant range from a given DME station. The outbound leg is flown according to the HDG corrections until the DME distance is obtained.

An adjusted HDG check may be applied while the time check on the inbound leg is not applicable.

Special Patterns

Holding patterns may be of a particular kind:

1. Intersection Holdings
2. Holdings with Secondary Fix
3. Non-Published Holdings

Intersection Holdings

Intersection Holdings are holdings where the holding fix is determined by crossing Lines of Position (LOP). The inbound course is determined by one LOP which is tracked outbound or inbound to the defining navigation aid.

Checks of the HDG corrections are not possible. In case of time patterns only the time check on the inbound leg is possible.

Holdings with Secondary Fix

In case of difficult terrain a secondary holding fix may be defined. While the primary holding fix is placed at the end of the inbound leg, the secondary holding fix determines the end of the outbound leg. The outbound turn and the inbound turn are used to intercept the outbound and the inbound leg, respectively.

An entry course line that provides a direct entry may lead to the secondary holding fix. In any case, only direct entries to the primary holding fix are authorized. Parallel and teardrop entries are forbidden.

Note: *Checks of the HDG and time corrections are not neccessary.* $MC_{outbound}$ *and* $MC_{inbound}$ *are just tracked.*

Non-Published Holdings

Non-Published Holdings are holdings where the holding fix is defined not by charts but determined by ATC or the instructor pilot. Holding fix may be any waypoint. The inbound course and the type of pattern (righthand or lefthand) must be given. At least the lefthand pattern must be ordered. All other cases comprise right hand patterns.

Checks of the HDG corrections of the $MH_{outbound}$ may not be possible.

Summary: Holdings

Outbound Leg

Pattern	HDG Corr.	Time Corr.	Checks
1 min	$3 \cdot WCA$	table(1 min)	15^o-check in inbound turn. Time check on inbound leg.
1.5 min	$2 \cdot WCA$	table(1.5 min)	10^o-check in inbound turn. Time check on inbound leg.
$>$ **1.5 min**	for 1.5 min: $2 \cdot WCA$ after 1.5 min: $1 \cdot WCA$	table value adjusted	Adjust check on inbound turn. Time check on inbound leg.
distance	for 1.5 min: $2 \cdot WCA$ after 1.5 min: $1 \cdot WCA$	time corr. N/A. Fly up to the DME distance	Adjust check on inbound turn.
intersection fix	accordingly, as above.	applicable only in case of time patterns.	HDG check N/A. Time check on inbound leg.
secondary fix	track to secondary fix	N/A	N/A

Table 6: Holdings and Race Track Patterns

4 Instrument Approach

An instrument approach towards a runway begins when leaving the airways. It is divided into the following segments:

1. The Standard Arrival Route (STAR)
2. Initial Approach Segment
3. Intermediate Approach Segment
4. Final Approach Segment
5. Missed Approach Segment
6. Visual Approach as final part of landing

4.1 The Standard Arrival Route (STAR)

The STAR begins at an Enroute Fix on an airway and ends at a holding fix which is usually also the Initial Approach Fix (IAF) of the selected instrument approach. The arrival route provides courses, distances, and Minimum Safe Altitudes (MSA).

The last MSA before reaching the IAF is called the Initial Approach Altitude (IAA). This is the Bottom of Descend (BOD) when descending from the cruise altitude.

4.2 Initial Approach Segment

The Initial Approach Segment begins at the IAF and ends at the Intermediate Fix (IF), or the Final Approach Fix (FAF) or Final Approach Point (FAP) in case no intermediate segment exists.

The Initial Approach Segment may contain one or more of the following Procedure Turns, also called Reversal Procedures or, short, Reversals:

1. Race Track Pattern
2. DME Arc
3. 45^o Procedure Turn
4. 80^o Procedure Turn
5. Base Turn

As long as the aircraft is flying a Procedure Turn the Initial Approach Segment is not yet completed.

Passing Fly-Over waypoints

In manual flight the IAF is a fly-over-waypoint. An approach angle less than $\pm 30^o$ off the first $MC_{outbound}$ after the IAF is called a Direct Approach. In case of a Base Turn this sector is extended to the extended RWY centerline. Approaches from a steeper angle require a Re-Interception after station passage with an interception angle of 30^o or 45^o.

4.2.1 Procedure Turns and Reversal Procedures

CRS reversals are necessary where only a few or even only one Navigational Aid (NAVAID) are providing signals for the instrument approach. The purpose of a Procedure Turn is to move the aircraft away from the runway on the extended runway centerline to an appropriate distance and to turn it around towards the runway. Therefore the Procedure Turns are called although Reversal Procedures, or short Reversals.

Race Track Patterns

Race Track Patterns are part of the approach and must be flown. The procedures are identical to the holding patterns and their entry procedures. The $MC_{inbound}$ of a race track pattern may be the same as the MC on intermediate or final approach. It shall be intercepted before station passage.

A Racetrack Pattern has two functions:

1. Reversal Procedure
2. Entry support for the approach

DME Arc

A DME-Arc is a curved track line in shape of a circle centered around a VORDME or VORTAC station.

Tracking the DME-Arc is performed as follows:

1. Fly a HDG so that the station is 5^o ahead of the wingtip.
2. Keep HDG until the station is 5^o aft of the wingtip.
3. Change HDG 10^o towards the station.
4. Repeat from step 1.

Note: *Here the VOR RMI is best suited for bearing indication.*

Wind Correction

During tracking of a DME-Arc the wind may change sides even in steady conditions due to the HDG changes. Active adjustment is required to keep the DME distance and counter the drift inside or outside the arc.

Note: *The distance tolerance during tracking is* ± 0.5 *NM.*

Entering the DME-Arc

The DME-Arc is entered while tracking a radial inbound or outbound. To avoid overshooting it is necessary to start the 90^o turn in an appropriate Distance of Lead (DoL).

Either the DoL is given in the IAC chart or it is calculated according to:

$$DoL_{[NM]} = \frac{GS_{[kt]}}{2} : 100$$

Note: *If the turn has to start at a given DoL, interception of the DME-Arc may be necessary.*

Note: *The formula for the DoL is used only up to GS 180 kt, to not exceed a bank angle of* 25^o*.*

Note: *For a particular A/C a fixed value may be given for the DoL for GS* $>$ $180\,kt$*.*

Leaving the DME-Arc

If a Leading Radial (LR) is given in the IAC chart the turn towards the next MC starts there.

Note: *In this case it may be necessary to intercept the MC.*

In case no LR is given start the turn at the appropriate AoL.

45^o **Procedure Turn**

The 45^o Procedure Turn outbound starts at a certain fix where

$$MC_{outbound} = MC_{inbound} + 180^o$$

This CRS is tracked with

$$MH_{outbound} = MC_{outbound} + WCA_{outbound}$$

The $MC_{outbound}$ has a Turnside where the 45^o Procedure Turn is performed and an opposite Non-Turnside.

The 45^o Procedure Turn is performed as follows:

- After 1 to 3 min tracking outbound (depending on the outbound limit) start the turn towards the turnside to the offset-CRS:

$$MC_{45^o} = MC_{outbound} \pm 45^o$$

- Turn to an offset-HDG of:

$$MH_{45^o} = MC_{45^o} + 2 \cdot WCA_{45^o}$$

- Fly this MH_{45^o} for 45 sec. Start the timer when on HDG.
- Apply a time correction according to the one-minute-table.
- When the time is up turn opposite 180^o to the MC_{180^o}.
- Fly on this CRS the HDG:

$$MH_{180^o} = MC_{180^o}$$

  This is a 45^o-interception HDG for the $MC_{inbound}$.
- Intercept and track $MC_{inbound}$.

Note: *The time distance from the begin of the $45^o P/T$ back to this point on reverse is approximately 3.5 min.*

Note: *The time distance from the begin of the $45^o P/T$ to the farthest point of the reversal (its "length") is 1.5 min.*

Note: *The time distance from the begin of the $45^o P/T$ to the intercept point on $MC_{inbound}$ is 60 sec.*

Note: *This procedure should be deleted because it is too complicated!*

If a 45^o procedure turn appears on charts an 80^o procedure turn is flown instead because it is allowed to fly an 80^o procedure turn in lieu of a 45^o procedure turn and vice versa.

80^o **Procedure Turn**

The 80^o Procedure Turn outbound starts at a certain fix where

$$MC_{outbound} = MC_{inbound} + 180^o$$

This CRS is tracked with

$$MH_{outbound} = MC_{outbound} + WCA_{outbound}$$

The $MC_{outbound}$ has a Turnside where the 80^o Procedure Turn is performed and an opposite Non-Turnside.
The 80^o Procedure Turn is performed as follows:

- After 1 to 3 min tracking outbound (depending on the outbound limit) start the turn towards the turnside.
- When reaching $MH_{80^o} = MC_{outbound} \pm 80^o$ reverse the turn to the opposite bank.
- Keep turning until $MH_{inbound} = MC_{inbound} + WCA_{inbound}$ is reached.
- Track $MC_{inbound}$.

Note: *The time distance from the begin of the $80^o P/T$ back to this point on reverse is approximately 2.5 min.*

Note: *The time distance from the begin of the $80^o P/T$ to the farthest point of the reversal (its "length") is 1 min.*

Note: *The time distance from the begin of the $80^o P/T$ to the intercept point on $MC_{inbound}$ is 40 sec.*

Wind corrections

Wind corrections for HDG and timing apply while in this particular case (and only here) headwind and tailwind get a new meaning:

- Wind from the Turnside is called "Headwind".
- Wind from the Non-Turnside is called "Tailwind".

Time Correction

In "Headwind" conditions when reaching MC_{80^o} the opposite turn is retarded for

$$t_{corr_{[sec]}} = 2 \cdot |WCA_{outbound_{[^o]}}|$$

before turning to the opposite side.

Note: *The $WCA_{outbound}$ is hereby taken in seconds instead of degree.*

Note: *Time corrections apply during "Headwind" conditions only.*

Heading Correction

In "Tailwind" conditions the MC_{80^o} is calculated according to

$$MH_{80^o} = MC_{outbound} \pm (80^o - |2 \cdot WCA_{outbound}|)$$

depending on the turnside.

Note: *HDG corrections apply during "Tailwind" conditions only. The offset angle is always reduced.*

Base Turn

A Base Turn comprises of

- a waypoint where the procedure turn outbound starts
- an outbound offset leg
- an inbound turn
- the inbound leg.

The length of the outbound leg is given either

- by distance or
- by time distance

If no length of the outbound leg is given the time distance can be estimated by

$$t_{D_{[min]}} \approx \frac{40}{\alpha_{[^o]}}$$

where α is the offset angle between outbound leg and inbound leg.

The Base turn is performed as follows:

- Track the $MC_{outbound}$.
- At the end of the outbound leg start the inbound turn.
- Track the $MC_{inbound}$.

4.3 Intermediate (Approach) Segment

The purpose of the intermediate segment is to allow the pilot to establish on final instrument CRS and to configure the aircraft.

Note: *Some approaches may not contain an intermediate segment.*

Note: *The intermediate CRS may differ up to 30^o from the final instrument CRS.*

The Intermediate Approach Segment begins at the Intermediate Fix (IF) and ends at the Final Approach Fix (FAF) or Final Approach Point (FAP).

Definition: The IF is reached when first time after completion of final inbound turn the A/C is on intermediate instrument CRS inbound in safe sector.

Note: *The IF may or may not be symbolized in the IAC chart.*

4.4 Final Approach Segment

The Final Approach Segment begins at the Final Approach Fix (FAF) in case of a non-precision approach or the Final Approach Point (FAP) in case of a precision approach and ends usually with the landing or at the Missed Approach Point (MAP).

Note: *The FAA does not discriminate between FAF and FAP, instead it calls it always FAF.*

The final approach segment determines whether the approach is a Precision Approach or a Non-Precision Approach. If only lateral guidance is provided it is a non-precision approach. With vertical guidance it is called a precision approach.

Straight-In-Landing vs Circle-To-Land

If the final instrument CRS leads to the RWY-centerline with a lateral angle less or equal to $\pm 30^o$ the approach is called Straight-In, else it is a Circle-To-Land approach which is a visual approach.

4.4.1 Non-Precision Approaches

A Non-Precision approach provides only lateral instrument guidance. Fix crossing altitudes are given and the last altitude before reaching the MAP is the Minimum Descend Altitude (MDA) or Minimum Descend Height (MDH), respectively.

Note: *Further descend below the MDA is allowed only if visual contact to the RWY is established and an appropriate Visual Descend Point (VDP) is reached.*

Note: *The VDP is calculated according to the TOD formula.*

Note: *In non-precision approaches without DME the RoD has to be increased by 100 fpm to descend to the MDA(H) always prior to the arrival at the MAP.*

4.4.2 Precision Approaches

A Precision approach provides lateral and vertical instrument guidance. The final segment of a precision approach begins at the Final Approach Point (FAP).

Note: *The FAP is reached whith Glide Path (GP) interceptfrom below when tracking the final instrument CRS.*

Note: *Precision approaches of CAT I and CAT II end at the DA if visual reference to the RWY is established. CAT III approaches need automated landing systems or HUD.*

Note: *Flying CAT I precision approaches is the last of the three qualitative steps the student pilot is trained during flight school. The first is learning to fly*

VFR, the second is learning to fly non-precision IFR. The last is learning to fly precision approaches of CAT I. To reach CAT II / III levels requires quantitative steps only (by exercise).

4.4.3 Final Altitude

Lufthansa checklists require a Final Altitude.

The Final Altitude is the fix crossing altitude at the Outer Marker (OM). If no OM is provided it is the fix crossing altitude at an appropriate fix in about 4 to 7 NM distance of the RWY. If no fix is available the Final Altitude is 1500 ft above ground level (AGL).

4.5 Missed Approach

The Missed Approach begins at the MAP or, for certified operators, at the VDP in case of a non-precision approach or at the DA in case of a precision approach and ends at the Missed Approach Fix, usually a holding fix.

The missed approach is described in the IAC chart.

4.6 Visual Approach

The last part of a non-precision final approach and precision final approaches down to CAT II are always visual approaches. That means, the pilot has to make visual contact to the RWY and land the A/C manually according to visual references.

4.6.1 Straight-In Visual Approach

Some instrument approaches provide Straight-In Visual Approaches on the last final. These visual approaches begin at the MAP of the instrument approach and end on the RWY.

They are depicted on the IAC.

4.6.2 Circle-To-Land

The Circle-To-Land approach is a visual approach. When the angle between the final instrument CRS and the RWY-centerline is greater than 30^o it is called a Circle-To-Land approach. It begins at the MAP of the instrument approach and ends with the landing or the commencement of the missed approach in case the visual contact to the RWY is lost.

Note: *It is the pilots responsibility to determine the entry into the visual traffic circuit to the active RWY and, if necessary, how to commence the missed approach.*

4.6.3 Circling Approach

The Circling Approach is the extreme case of an Circle-To-Land approach. Usually used due to tailwind conditions, the Circling Approach joins the traffic circuit at the instrument approach opposite to the active RWY at the MAP.

Approach restrictions may apply, like speed limits or the prescribed turn side.

Note: *This procedure depends on the aircraft. Please refer to the AOM or OM-B for details.*

Note: *LH and BW commence the Circling Approach with a* 45^o *offset CRS. This allows to turn after downwind with SRT directly onto final without flying a base leg.*

As a given rule, when on downwind, after abeam passing the end of the RWY fly a time distance of

$$t_{D[sec]} = 3[sec] \cdot \frac{\Delta H_{[ft]}}{100\,ft}$$

before starting the final turn.

The RoD for the turn and final approach can be calculated according to the following rule of thumb:

$$RoD \approx \frac{2000 \cdot \Delta H_{[ft]}}{2000 + \Delta H_{[ft]}}[fpm]$$

Examples are given in the following table:

RoD in Circling Approach

$\Delta H[ft]$	$RoD[fpm]$
2000	1000
1500	860
1000	666.666
600	460

Table 7: RoD in Circling Approach

On the other hand, if a fixed RoD = 1000 fpm is chosen the outbound time on downwind after abeam THR is always 60 sec, independent of the speed and altitude. After 60 sec the TOD is reached and the descend and turn towards the RWY can be commenced.

4.7 Ground Controlled Approaches

Ground Controlled Approaches (GCA) are instrument approaches controlled by ATC. No on-board equipment other than VHF-COM is required. Typically IAC charts are rarely provided and no missed approach procedure is prescribed.

Information about holdings, the missed approach procedure in case of communication failure, altimeter settings, altitudes, etc is issued by the controller to the pilot prior to the start of the approach. The pilot has to confirm the orders.

After the controller intructs "Do not confirm further instructions!" the pilot has not to confirm orders. Orders given with the addition "Acknowledge!" must be confirmed by the pilot.

Lost contact with the controller requires transition to the missed approach.

Note: *The minimums are published in the according IAC charts.*

4.7.1 Non-Precision: SRE Approach

The Surveillance Radar Equipment (SRE) Approach is the non-precision variant of the GCA. The controller gives radar vectors and recommended altitudes to the final of the active RWY.

Lost contact with the controller requires transition to the missed approach after approximately

- 1 min when vectored
- 15 sec on final

Note: *The SRE approach is also called Aerodrome Surveillance Radar (ASR) Approach.*

4.7.2 Precision: PAR Approach

The Precision Approach Radar Approach is the precision variant of the GCA. The controller is equipped with special radar system, called Precision Approach Radar (PAR), to control the centerline and the glide path to the active RWY.

Lost contact with the controller requires transition to the missed approach after

- 5 sec on final

Note: *To assure the pilot of the established contact the controller keeps talking continuously. Therefore this procedure is called "Talk Down" (German: "Heruntersprechen").*

4.8 Callout Procedures

On the final part of the instrument flight the flight crew has, besides its other duties, to communicate in form of standardized phrases to keep everybody in the cockpit on the same level of information. This section gives hints of the callout procedures.

Note: *The actual standard and abnormal callout procedures are described in the OM-B (AOM) of the particular aircraft.*

4.8.1 Standard Callout Procedures

During final, besides the reading of checklists and approach briefing, standardized callouts have to be made by the members of the flight crew. Idealized callouts are given in the following tables.

Note: *The flight crew has to consult the OM-B(AOM) for the correct phrases.*

Example: Civil Standard Callout Procedures

Condition	Call-Out	Flight Crew Member
Passing final fix	fix/Final Altitude Checked	PNF
1000 ft radio altimeter	One Tousand Checked	PNF/Both
500 ft above TDZE	Five Hundred/Checked	PNF/PF
100 ft above minimum	Hundred Above	PNF
Appr.lights/RWY in sight	Appr.Lights/RWY ahead	PNF
Visual contact	In Sight	PF
At minimum	Minimum	PNF
visual contact	Continue	CM1
400 ft AGL (radio altimeter)	Four Hundred	CM3 or PNF
300 ft AGL (—"—)	Tree Hundred	CM3 or PNF
200 ft AGL (—"—)	Two Hundred	CM3 or PNF
100 ft AGL (—"—)	One Hundred	CM3 or PNF
50 ft AGL (—"—)	Fifty	CM3 or PNF
40 ft AGL (—"—)	Forty	CM3 or PNF
30 ft AGL (—"—)	Thirty	CM3 or PNF
20 ft AGL (—"—)	Twenty	CM3 or PNF
10 ft AGL (—"—)	Ten	CM3 or PNF
	or	
NO visual contact	Go-Around	CM1

Table 8: Civil Standard Callout Procedures

Example: BW Standard Callout Procedures

Condition	Call-Out	Flight Crew Member
Passing fix on final inbound	Fix Crossing Altitude Checked	PNF
Approaching minimum	Approaching Minimum	PNF
Reaching the MDA	MDA	PNF
Appr.lights/RWY in sight	Appr.Lights/RWY ahead	PNF
At minimum	Minimum	PNF
Visual contact	In Sight	PF
Unable to continue	Go-Around	IP

Table 9: BW Standard Callout Procedures

4.8.2 Abnormal Callout Procedures

Everyone who recognizes an abnormal situation shall alert the flight crew. Warnings concerning instrument flight procedures should be given e.g. on the following abnormal deviations:

Abnormal Callout Procedures

Abnormal Callout on ...
... deviations from the approach path,
... deviations from the required aircraft configuration,
... deviations from the altitudes specified for the approach procedure,
... deviations from the target speed of plus 10 kt or minus 5 kt, and more, together with the tendency of change (increasing/decreasing),
... rate of descent (RoD) in excess of 1000 fpm below 1000 feet,
... malfunctions of instruments or indications, approach and landing aids,
... bank angles exeeding 30 degrees,
... etc.

Table 10: Abnormal Callout Procedures

4.9 Radio Setup

The tuning of radios and use of navigation systems depends strongly on the equipment of the particular aircraft.

The principle is the preparation of the radio frequencies according to the sequence in which the navigation systems are used during the flight phases and the instrument approach.

Note: *Only an idealized radio setup can be described. For more information see the OM-B (AOM) of the particular aircraft.*

Civil Radio Setup

Approach	**active ADF**	**standby ADF**	**VHF-NAV1**	**VHF-NAV2**
NDB	Approach Fix	LMM, LOM, other NDB	as suitable	as suitable
VOR	as suitable	as suitable	main VOR	other VOR
ILS-Back Beam	as suitable	as suitable	ILS	ILS, VOR/DME
ILS	as suitable	as suitable	ILS	VOR, on LOC / OM: ILS

Table 11: Civil Radio Setup

Note: *Lufthansa calls this procedure also "Navaid Setting"*

4.10 Situational Awareness

Situation awareness is the perception of circumstances with respect to time or space, the comprehension of their meaning, and the projection of their status after some variable has changed. It describes the mental model of the situation.

It is critical to decision-makers in complex, dynamic areas like aviation.

Lacking or inadequate situation awareness has been identified as one of the primary factors in accidents attributed to human error. Thus, situation awareness is especially important in work domains where the information flow can be quite high and poor decisions may lead to serious consequences (e.g., piloting an airplane).

Situation awareness has been recognized as a critical, yet often elusive, foundation for successful decision-making across a broad range of complex and dynamic systems, including aviation and air traffic control. In particular, it describes the ability of the pilot to be oriented, to know where the aircraft is located and to know the correct direction to take to perform the required navigational problem or procedure. [8]

According to the experience of instructor pilots in teaching student pilots small aircraft instrument procedure flying the

Three Basic Mistakes in Instrument Flying
are:

1. **Being Outside Minimum Altitude & Flight Path Requirements.** This includes while:

   A. On published routes, STARs, departure procedures, approaches, missed approaches, obstacle departures and other charts where minimum altitudes are indicated or climb gradients are required.

   B. Flying off published airways, routes, approaches, and other established and written procedures, being below minimum (ATC makes mistakes). This would include being outside safe sector while on approach.

2. **Mistuning of Radios.**
   A. Mistuning the frequency.

   B. Not identifying the station.

   C. Mis-selecting the CRS.

   D. Not recognizing a malfunktion of the navigational equipment.

   E. Selecting the wrong station.

   F. Mis-use of the "Hold" function of the DME so that the incorrect station is being used.

   G. Not leaving the identifier on throughout a NDB approach.

H. Not comparing the DG to the magnetic compass for correct alignment.

3. **Disorientation** This includes:

   A. Spatial disorientation or vertigo.

   B. Disorientation in navigation, or not knowing where the aircraft is located, or not knowing the correct direction to take to perform the required navigational problem or procedure.

[6]

Note: *Passing ILS side lobes may cause confusion.*

Descent below the minimum safe enroute altitude/minimum safe grid altitude to the minimum sector altitude may be made when approaching the navigation aid from which an approach-to-land will be conducted, provided the aircraft's position can be accurately established as being within 25 NM from the navigation aid upon which the minimum sector altitude is based by

- the use of a radio navigational aid or
- positive radar control.

When being radar vectored, clearance to descend below the minimum sector altitude may be accepted, provided the pilot is able to monitor the aircraft's position using the available radio navigational aids.

5 Area Navigation (RNAV) Procedures

Area Navigation (RNAV) is a method of navigation that permits aircrafts to approach any waypoint on any desired course. It requires a minimum of certified aircraft equipment with specified navigation systems and sensors. RNAV or Required Navigational Performance (RNP) based procedures, respectively, require limits of the Total System Error (TSE) [4].

RNAV based IFP are usually performed with auto pilot and flight guidance systems (Managed Guidance). In manual flight (Selected Guidance) there is no principal difference between conventional IFP and RNAV procedures. Only published procedures shall be flown.

Slightly different information representation allows more flexibility in the procedures than conventional equipment.

Note: *In waypoint navigation, other than VOR or ILS navigation, the course deviation is represented as Cross Track Error (XTK) rather than Track angle Error (TKE).*

RNAV approaches are defined by the coordinates of waypoints (WP). These coordinates are stored in the database of the certified flight guidance system. Based on these waypoints the desired trajectories are calculated. The determination of the actual trajectory is performed by measurement of the actual aircraft position. The subsequent evaluation allows the adjustment of the predefined flightpath. Based upon this the Flight Guidance Computer (FGC) calculates the neccessary guidance targets.

There exist two kinds of waypoints: fly-over WPs and fly-by WPs. A fly-over WP must be passed. Fly-by WPs are used to determine the tangents to the flight path at the beginning an the end of the turn.

5.1 RNAV specific Procedures

Automatically flown RNAV procedures differ significantly from manually flown procedures (e.g. holdings). But with the information displayed by the RNAV system also manual instrument flight is possible.

5.1.1 Offset Tracking

Conventional IFR equipment provides information to track course lines. But because the indicated course deviation is based upon TKE it is not possible to fly parallel to a given couse line.

With the RNAV indication of course deviations based on XTK it is possible to track parallel offset to a given course line and keep a desired distance. This is possible under managed as selected guidance alike.

5.1.2 RNAV Approach Patterns

In the terminal area the RNAV transitions (SIDs, STARs) are performed according to the standard procedures.

While under selected guidance the IAF is a fly-over waypoint, under managed RNAV guidance it is a fly-by waypoint.

In the final approach segment the standard procedures are used. The flexible design of approach procedures made possible by RNAV is already in use. It is expected that RNAV approaches are realized as Continuous Descent Final Approaches (CDFA).

Note: *Compare the RNAV approach pattern in Bremen or the GPS approach of Goodyear, AZ, to conventional IFR approaches.*

RNAV and RNP approaches can be non-precision or precision approaches. MDA or DA are provided respectively.

Note: *There may be cases where MDA or VDP are used as DA.*

Lateral Navigation (LNAV), Localizer Performance (LP) are flown as non-precision approaches.

Approaches with vertical guidance (APV), Lateral Navigation with vertical guidance (LNAV/VNAV), Localizer Performance with vertical guidance (LPV), are flown as precision approaches.

GNSS Landing System (GLS) Approaches belong to the class of precision approach systems.

Summary:Instrument Landing Systems

Instrument Landing Systems

Precision Systems	***Non-Precision Systems***
APV, LNAV/VNAV, LPV, ILS, GLS, MLS, PAR	VOR, LP, LOC, LOC-BB, NDB, GPS, LNAV

Table 12: Instrument Landing Systems

In any case, except precision approaches of CAT III, for conventional instrument approaches two minimum values are provided:

Approach Minimums

Instrument Approach	***vertical Minimum***	***horizontal Minimum***
Non-Precision	MDA(H)	VIS or RVR
Precision CAT I	DA(H)	VIS or RVR
Precision CAT II	DA(H)	RVR
Precision CAT III	—	(RVR)

Table 13: Approach Minimums

Note: *Approaches are flown manually down to CAT II. Manual landing with CAT III requires special equipment (Head-Up Display HUD).*

6 Emergency Procedures

6.1 SRT without Rate and Turn Coordinator

For a 360^o-Turn:

- Keep ALT.
- Fly left or right turn with bank angle $\beta_{[^o]} = \frac{TAS_{[kt]}}{10} + 7^o$ for 2 min.

For a 180^o-Turn:

- Keep ALT.
- Fly left or right turn with bank angle $\beta_{[^o]} = \frac{TAS_{[kt]}}{10} + 7^o$ for 1 min.

6.2 Homing

Just follow the RMI needle. Fly the Relative Bearing (RB) to zero.

Note: *Due to the wind the ground track, the so called dogleg, is not under control of the pilot.*

Note: *Homing is possible only inbound to station.*

6.3 80^o Time Distance Check

This Procedure is used to determine the Time Distance t_D to a navigation aid.

1. Fly $MH_{80^o} = MB_{ToStation} \pm 80^o$, whatever is closer to your previous heading.
2. Start the timer when the RMI needle is 5^o foreward of the wingtip at t_1.
3. Stop the timer when the RMI needle is 5^o aft of the wingtip at t_2.
4. Calculate the intermediate flying time $\Delta t = t_2 - t_1$ in seconds.
5. Time distance to the station is $t_D = \frac{\Delta t}{10}$ in minutes.
6. Commence your previous heading.

Note: *The so measured time distance contains an error of about* $\pm 10\%$.

6.4 Interceptions with partial Panel

The following procedures are used exclusively with NDB's in case of loss of ADF-RMI compass information. They are applicable with a radio compass or otherwise available Relative Bearing (RB).

6.4.1 Inbound Interception with RB only

- Change MH so that RB becomes zero. Then $MH = MB_{To}$.
- If the difference between MH (MB_{To}) and $MC_{desired}$ (G) is less than $60^o$the $MH_{interception}$ is reached with an additional 30^o HDG change:
- If $MC_{desired} < MB_{To}$ fly $MH_{Int} = MH + 30^o$ to the right.
- If $MC_{desired} > MB_{To}$ fly $MH_{Int} = MH - 30^o$ to the left.
- $MC_{desired}$ is reached if the angle between the lubberline and the needle equals the interception angle ($i = MC_{desired} - MH_{intercept}$).

If the angle between $QDM_{desired}$ and QDM_{actual} (G) is greater than 60^o the according procedure (interception with $G > 60^o$) is applied.

6.4.2 Outbound Interception with RB only

- Fly $MH = MC_{desired}$.
- In case the needle points to the right change HDG to $MH_{Int} = MC_{desired} + 45^o$.
- In case the needle points to the left change HDG to $MH_{Int} = MC_{desired} - 45^o$.
- The $MC_{desired}$ is reached if $RB = 135^o$ or $RB = 225^o$, respectively.

7 Rules of Thumb

This section contains the derivation or listing of all herein used rules of thumb.

7.1 One-In-Sixty Rule

Circumpherence U of the unit circle:

$$U = 2\pi \triangleq 360^o$$

$$\Rightarrow \frac{1RAD}{1^o} = \frac{U}{360^o} = \frac{2\pi}{360^o} = \frac{\pi}{180^o} \approx \frac{3}{180} = \frac{1}{60}$$

Interpretation:

1. Use the 1-in-60-Rule to convert degree into radiant: $\alpha_{[RAD]} = \alpha_{[^o]} \cdot \frac{\pi}{180^o} \approx \alpha \cdot \frac{1}{60}$
2. A Track Angle Error (TKE) of 1^o results in a Cross Track Error (XTK) of 1 NM in 60 NM distance. (Hence the name 1-in-60-Rule).
3. For small angles α ($\leqq 15^o$) $\sin(\alpha)$ and $\tan(\alpha)$ are approximately equal to α in radiant.

7.2 Trigonometric Functions

To calculate trigonometric functions, use:

$$sin(0^o) = 0$$

$$sin(10^o) \approx 0.2$$

$$sin(\alpha) \approx \frac{\alpha}{100} + 0.2$$

$$sin(90^o) = 1$$

$$cos(\alpha) = sin(90^o - \alpha)$$

If $\alpha \leqq 15^o$ then use the 1-in-60-Rule:

$$sin(\alpha) \approx tan(\alpha) \approx \frac{\alpha}{60}$$

because the Taylor series expansions of the sinus and tangens of an angle α are in first approximation equal to α in radiant:

$$sin(\alpha) = \frac{\alpha}{1!} - \frac{\alpha^3}{3!} + \frac{\alpha^5}{5!} - \frac{\alpha^7}{7!} \pm ...$$

$$\Rightarrow sin(\alpha) \approx \frac{\alpha}{1!} = \alpha_{[RAD]}$$

$$tan(\alpha) = \alpha + \frac{1}{3} \cdot \alpha^3 + \frac{2}{15} \cdot \alpha^5 + \frac{17}{315} \cdot \alpha^7 + ...$$

$$\Rightarrow tan(\alpha) \approx \alpha_{[RAD]}$$

7.3 True Airspeed (TAS)

$$TAS \approx CAS + 2 \cdot \frac{FL}{10} \qquad if\; TAS \leqq 150\, kt.$$

$$TAS \approx CAS + 3 \cdot \frac{FL}{10} \qquad if\; TAS > 150\, kt.$$

where

$$CAS \approx IAS$$

7.4 Standart Rate Turn (SRT)

In a SRT the RoT is $3 \frac{o}{sec}$. Therefore a 360^o-Turn takes 2 minutes. So, the circumference U of the 360 in time distance is

$$2min = U = 2\pi\, R$$

$$\Rightarrow R = \frac{120\, sec}{2\pi} \approx \frac{120\, sec}{2 \cdot 3} = 20\, sec$$

The radius R of a SRT in time distance is

$$R \;=\; 20\, sec$$

7.5 Wind Correction Angle (WCA), Ground Speed (GS) and other Components

Wind Angle wa:

$$wa = W - TC$$

Crosswind Component CWC:

$$CWC = V \cdot sin(wa)$$

Wind Component WC:

$$WC = -V \cdot cos(wa)$$

where the WC is a negative Headwind Component (HWC) or a positive Tailwind Component (TWC).

Another way to calculate the WC is

- Calculate $110 - wa$. This is the percentage of the wind speed V which is the WC.
- For $wa = 80^o$ use 20% instead of 30%.
- For $wa = 90^o$ WC = 0 kt.
- For $wa = 0^o$ WC = V.

Effective true airspeed:

$$TAS_{effective} = \sqrt{TAS^2 - CWC^2}$$

or, if the WCA is already known

$$TAS_{effective} = TAS \cdot cos(WCA)$$

Groundspeed GS:

$$GS = TAS_{effective} + WC$$

$$GS \approx TAS + WC$$

Wind Correction Angle WCA:

$$WCA = arcsin(\frac{CWC}{TAS}) = arccos(\frac{TAS_{effective}}{TAS})$$

$$\Rightarrow \frac{CWC}{TAS} = sin(WCA) \approx \frac{WCA}{60}$$

$$\Rightarrow WCA \approx \frac{CWC}{\frac{TAS}{60}} = \frac{V}{\frac{TAS}{60}} \cdot sin(wa) = WCA_{max} \cdot sin(wa)$$

where the maximal WCA is

$$WCA_{max} = \frac{V}{\frac{TAS}{60}}$$

and $\frac{TAS}{60}$ are the airmiles per minute.

7.6 Bank Angle (β)

Gravitation:

$$F_G = m \cdot g$$

with acceleration g due to gravitation.

Centrifugal force:

$$F_Z = m \cdot \frac{v_T^2}{r}$$

with turning radius r.

Tangential velocity:

$$v_T = \frac{2\pi r}{T}$$

with period: T.

$$v_T = \frac{2\pi r}{T} = \frac{2\pi}{T} \cdot r = \omega \cdot r$$

Angular velocity SRT: $RoT = \omega = 3[\frac{o}{s}]$, velocity: $v_T = TAS[kt]$

$$tan\beta = \frac{F_Z}{F_G} = \frac{m \cdot \frac{v_T^2}{r}}{m \cdot g} = \frac{v_T^2}{r \cdot g} = \frac{v_T}{r} \cdot \frac{v_T}{g} = \omega \cdot \frac{v_T}{g} \qquad because \quad \omega = \frac{v_T}{r}$$

or

$$tan\beta = \frac{RoT \cdot TAS}{g}$$

$$tan\beta = \frac{3[\frac{o}{s}] \cdot \frac{\pi}{180^o} \cdot TAS[kt] \cdot \frac{\frac{1852[m]}{3600[s]}}{[kt]}}{9.91[\frac{m}{s^2}]}$$

$$\Rightarrow \quad tan\beta = 0.00275_{[\frac{1}{kt}]} \cdot TAS_{[kt]}$$

$$\Rightarrow tan\beta \approx \frac{\beta}{60} \approx 0.00275 \cdot TAS$$

$$\Rightarrow \beta \approx \frac{TAS}{10} \cdot 0.0275 \cdot 60 = \frac{TAS}{10} \cdot 1.65 \approx \frac{TAS}{10} \cdot 1.5$$

or

$$\beta \approx \frac{TAS}{10} + 50\%$$

which formula fits low speed turns better than high speed turns.

Maneuvers are performed with a TAS between 100 kt and 200 kt.

Average maneuver TAS 150 kt:

$$\Rightarrow \beta \approx \frac{150}{10} \cdot 1.5 = 22.5^o = \frac{TAS}{10} + 7.5^o \approx \frac{TAS}{10} + 7^o$$

Lufthansa therefore uses

$$\beta \approx \frac{TAS}{10} + 7^o$$

which formula fits high speed turns better than low speed turns.

7.7 Rate of Descent (RoD)

$$\frac{3}{60} \approx tan(3^o) = \frac{RoD_{[kt]}}{GS_{[kt]}}$$

$$\Rightarrow \qquad RoD_{[kt]} \approx \frac{3}{60} \cdot GS_{[kt]}$$

with

$$1kt = 1\frac{NM}{h} \approx \frac{6000\,ft}{60\,min} = 100\,fpm$$

follows

$$RoD_{[fpm]} \approx \frac{3}{60} \cdot GS_{[kt]} \cdot 100[\frac{fpm}{kt}]$$

$$\Rightarrow \qquad RoD_{[fpm]} \approx 5 \cdot GS_{[kt]}.$$

So, the relation is

$$\frac{GlideSlope\,3^o}{Factor\,5} = 0.6 \approx 0.5 = \frac{1}{2}[\frac{o}{\Delta Factor\,1}]$$

or the other way around:

$$\frac{Factor\,5}{GlideSlope\,3^o} = 1.\overline{6} \approx 2[\frac{\Delta Factor}{1^o}] = \frac{2}{10}[\frac{\Delta Factor}{0.1^o}]$$

7.8 Top of Descent (d_{TOD})

$$\frac{3}{60} \approx tan(3^o) = \frac{\Delta ALT_{[NM]}}{d_{TOD[NM]}}$$

$$\Rightarrow \qquad d_{TOD[NM]} \approx \frac{60}{3} \cdot \Delta ALT_{[NM]}$$

with

$$1\,NM \approx 6000\,ft$$

follows

$$d_{TOD[NM]} \approx \frac{60}{3} \cdot \Delta ALT_{[NM]} \approx \frac{60}{3} \cdot \Delta ALT_{[NM]} \cdot \frac{1}{6000}[\frac{ft}{NM}] = \frac{\Delta ALT_{[ft]}}{300}$$

or with

$$1\,FL = 100\,ft$$

$$\Rightarrow \qquad d_{TOD[NM]} \approx \frac{\Delta FL}{3}$$

This is the formula in use by LH and the LBA.

On the other hand

$$d_{TOD[NM]} \approx \frac{\Delta ALT_{[ft]}}{300} = \frac{1}{3} \cdot \frac{\Delta ALT_{[ft]}}{100} \approx \frac{3}{10} \cdot \frac{\Delta ALT_{[ft]}}{100}$$

because

$$\frac{1}{3} = 0.333... \approx 0.3 = \frac{3}{10}$$

Therefore ATCA uses

$$d_{TOD[NM]} \approx \frac{\Delta ALT_{[ft]}}{1000} \cdot 3$$

7.9 Angle of Lead $(AoL_{\perp})$

$$\frac{AoL_{\perp[^o]}}{60} \approx tan(AoL_{\perp}) = \frac{R_{[s]}}{t_{D[s]}}$$

$$\Rightarrow \qquad AoL_{\perp}[^o] \approx \frac{R_{[s]}}{t_{D[s]}} \cdot 60[\frac{s}{min}] = \frac{20}{t_{D[min]}}$$

With

$$GS_{[kt]} = \frac{DME_{[NM]}}{t_{D[h]}} = \frac{DME_{[NM]}}{t_{[min]}} \cdot 60[\frac{min}{h}]$$

$$\Rightarrow \qquad t_{D[min]} = \frac{60 \cdot DME_{[NM]}}{GS_{[kt]}}$$

Therefore

$$AoL_{\perp}[^o] \approx \frac{20}{t_{D[min]}} = \frac{20}{\frac{60 \cdot DME_{[NM]}}{GS_{[kt]}}} = \frac{GS_{[kt]}}{3} : DME_{[NM]}$$

7.10 Angle of Lead as Function of Interception Angle (AoL(i))

$$\frac{AoL(i)_{[^o]}}{60} \approx tan(AoL(i)) = \frac{x_{[s]}}{t_{D[s]}}$$

Because AoL(i) is small

$$cos(i) \approx \frac{R - x}{R}$$

$$\Rightarrow \qquad x \approx R - R \cdot cos(i) = R \cdot (1 - cos(i))$$

Therefore

$$AoL(i) \approx \frac{x}{t_D} \approx \frac{R \cdot (1 - cos(i))}{t_D} = \frac{20}{t_D} \cdot (1 - cos(i)) = AoL_{\perp} \cdot (1 - cos(i))$$

7.11 Distance of Lead (DoL)

$$DoL = GS \cdot R$$

where R = 20[sec] is the SRT radius in time distance.
Because

$$20[sec] = \frac{1}{3}[min] \approx \frac{3}{10}[min] = \frac{3}{10} \cdot \frac{1}{60}[h] = \frac{1}{200}[h]$$

$$\Rightarrow \qquad DoL_{[NM]} \approx \frac{GS_{[kt]}}{200} = \frac{GS_{[kt]}}{2} : 100$$

or: The DoL in NM is approximately a $\frac{1}{2}$% of the value of the GS in kt.

Another rule of thumb of unknown provenience is

$$DoL_{[NM]} \approx 10 \cdot M - 0.2\,[NM]$$

7.12 LOP for HDG Check in Time Holdings

The offset angle α of the LOP for the HDG check in one minute holding patterns is 15^o. Offset angles of the LOP in longer time patterns may be calculated using

$$tan(\alpha) = \frac{20s}{t_{inbound}[s] + 20s}$$

$$\Rightarrow \qquad \frac{\alpha}{60} \approx tan(\alpha) = \frac{20s}{t_{inbound}[s] + 20s}$$

therefore

$$\Rightarrow \qquad \alpha_{[^o]} \approx \frac{\frac{1}{3}min}{t_{inbound}[min] + \frac{1}{3}min} \cdot 60 \approx \frac{15}{t_{inbound}[min]}$$

7.13 Baseturn Outbound Timing

Given a Baseturn without outbound timing or distance calculate the offset angle

$$\alpha = MC_{inbound} - MC_{outbound}$$

$$tan(\frac{\alpha}{2}) = \frac{R}{t_D}$$

$$\Rightarrow \quad \frac{\frac{\alpha}{2}}{60} \approx tan(\frac{\alpha}{2}) = \frac{R}{t_D}$$

$$\Rightarrow \quad t_{D[s]} \approx \frac{20\ s}{\frac{\alpha}{2}} \cdot 60_{[\frac{s}{min}]}$$

$$\Rightarrow \quad t_{D[min]} \approx \frac{20}{\frac{\alpha}{2}}$$

$$\Rightarrow \quad t_{D[min]} \approx \frac{40}{\alpha}$$

This is the time distance to fly the offset CRS outbound. It has to be corrected for the WC according to the 1 min - time correction table.

7.14 $80^o - T/D$-Check

This T/D-Check is performed abeam the station. A BRG change $G = 10^o$ around RB 090 or RB 270 is observed and the time Δt to fly G is measured.

The time distance to the station is then

$$\frac{G}{60} \approx tan(G) = \frac{\Delta t_{[s]}}{t_{D[s]}}$$

$$\Rightarrow \quad \frac{t_{D[s]}}{60[\frac{s}{min}]} \approx \frac{\Delta t_{[s]}}{G}$$

$$\Rightarrow \quad t_{D[min]} \approx \frac{\Delta t_{[s]}}{10}$$

7.15 ΔFL from Tilt Angle

To check whether it is possible to climb over a Cumulo Nimbus (CB) use the following procedure:

- Tilt the WX-Radar up and read the tilt angle α where display of the precipitation fades away.
- Multiply the range r to the CB with the tilt angle α and get the ΔFL to climb.
- Add the ΔFL to the actual FL and decide whether to climb ot to avoid.

This is because

$$tan(\alpha) = \frac{\Delta FL}{r}$$

$$\frac{\alpha}{60} \approx tan(\alpha) = \frac{\Delta FL}{r}$$

$$\Rightarrow \qquad \Delta FL_{[100\,ft]} \approx r_{[NM]} \cdot \frac{\alpha}{60} \cdot \frac{6000\,ft}{NM} \cdot \frac{1\,FL}{100\,ft}$$

therefore

$$\Delta FL \approx r \cdot \alpha$$

7.16 Tilt Angle Down for ALT X-Check

The WX-Radar in WX-mode can be used for a cross check of the barometric altimeter in level flight over low and level terrain:

- Tilt down the beam to a certain angle α. This angle depends on the aircraft; Ask an experienced pilot on the value of this tilt angle and the gain setting. Usually Full Down (15^o).
- Read the range of the nearest fringe.
- Multiply the range number times 2000.
- Compare the result to the ALT.

This is because

$$tan(\alpha) = \frac{ALT}{r}$$

$$\Rightarrow \qquad ALT_{[ft]} = r_{[NM]} \cdot tan(\alpha) \cdot f_{[\frac{ft}{NM}]}$$

with

$$f = 6076 \frac{ft}{NM}$$

and the tilt angle plus beam width

$$\alpha = 15^o + 3^o = 18^0$$

follows

$$ALT_{[ft]} \approx r_{[NM]} \cdot 2000 \frac{ft}{NM}$$

7.17 Mach Number (M)

The Mach number M is defined by

$$M = \frac{TAS}{a}$$

where a is the speed of sound. a depends only on the air temperature T:

$$a_{[\frac{m}{s}]} \approx 20 \cdot \sqrt{T_{[^oC]} + 273^o}$$

7.18 Circling Approach Timing

When on downwind of a Circling Approach the given rule for timing outbound from abeam THR is to fly outbound three seconds for every 100 ft height to loose:

$$t_{out} = \Delta H_{[ft]} \cdot \frac{3\,sec}{100\,ft} = \Delta H_{[ft]} \cdot \frac{0.5\,min}{1000\,ft} = \frac{\Delta H_{[ft]}}{2000\,fpm}$$

After t_{out} the TOD is reached and the descend towards the RWY begins with a 180^o SRT:

$$t_{TOD} = t_{out}$$

To calculate the RoD for turning base and final we have $t_{in} = t_{out}$ and $t_{\frac{SRT}{2}} = 1\,min$. The Total Time t_{TTL} is

$$t_{TTL} = t_{out} + t_{Desc} = t_{out} + t_{\frac{SRT}{2}} + t_{in} = 2 \cdot t_{out} + 1\,min$$

with the Descend Time t_{Desc}

$$t_{Desc} = t_{\frac{SRT}{2}} + t_{in} = \frac{\Delta H_{[ft]}}{RoD_{[fpm]}}$$

Therefore

$$t_{TOD} = t_{out} = t_{TTL} - t_{Desc}$$

$$\Rightarrow \frac{\Delta H_{[ft]}}{2000\,fpm} = 2 \cdot \frac{\Delta H_{[ft]}}{2000\,fpm} + 1\,min \cdot \frac{\Delta H_{[ft]}}{\Delta H_{[ft]}} - \Delta H_{[ft]} RoD_{[fpm]}$$

Divided by ΔH:

$$\frac{1}{2000\,fpm} = \frac{1}{1000\,fpm} + \frac{1\,min}{\Delta H_{[ft]}} - \frac{1}{RoD_{[fpm]}}$$

$$\Rightarrow \frac{1}{2000\,fpm} - \frac{1}{1000\,fpm} - \frac{1\,min}{\Delta H_{[ft]}} = -\frac{1}{RoD_{[fpm]}}$$

$$\Rightarrow \frac{1}{1000\,fpm} - \frac{1}{2000\,fpm} + \frac{1\,min}{\Delta H_{[ft]}} = \frac{1}{RoD_{[fpm]}}$$

$$\Rightarrow \frac{2-1}{2000\,fpm} + \frac{1}{\Delta H_{[fpm]}} = \frac{1}{RoD_{[fpm]}}$$

$$\Rightarrow \frac{\Delta H_{[fpm]} + 2000\,fpm}{\Delta H_{[fpm]} \cdot 2000\,fpm} = \frac{1}{RoD_{[fpm]}}$$

and so we have finally:

$$RoD_{[fpm]} = \frac{2000 \cdot \Delta H_{<ft>}}{2000 + \Delta H_{<ft>}} [fpm]$$

where the brackets <> mean to enter just the quantity, without the unit. With this formula the RoD can be calculated according to the downwind height.

If, on the other hand, a fixed $RoD = 1000\,fpm$ is used the formula for t_{out} provides us with

$$\Delta H_{[ft]} = 2000\,fpm \cdot t_{out_{[min]}}$$

Inserted into the formula for RoD results in

$$1000\,fpm = \frac{2000\,fpm \cdot 2000\,fpm \cdot t_{out_{<min>}}}{2000\,fpm + 2000\,fpm \cdot t_{out_{<min>}}}$$

$$\Rightarrow \quad 1000\,fpm = 2000\,fpm \cdot \frac{t_{out_{<min>}}}{1 + t_{out_{<min>}}}$$

$$\Rightarrow \quad \frac{1}{2} \cdot (1 + t_{out_{<min>}}) = t_{out_{<min>}}$$

$$\Rightarrow \quad \frac{1}{2} + \frac{1}{2} \cdot t_{out_{<min>}} = t_{out_{<min>}}$$

$$\Rightarrow \quad \frac{1}{2} = t_{out_{<min>}} - \frac{1}{2} \cdot t_{out_{<min>}} = \frac{1}{2} \cdot t_{out_{<min>}}$$

$$\Rightarrow \quad \frac{1}{2} \cdot t_{out_{[min]} = \frac{1}{2}\,min}$$

$$\Rightarrow \quad t_{out} = 1\,min$$

This describes the following procedure ("**Circling Paradoxon**"):

1. Fly the circling approach downwind from abeam THR for one minute straight and level, then
2. start the descend with SRT and a constant $RoD = 1000\,fpm$.
3. Rolling out on final, this RoD leads directly to the THR of the RWY.

Note: *This procedure is independent of speed and height of the A/C.*

After 60 seconds the descend can be started with $RoD = 1000\,fpm$, independent from circling ALT. The TOD on downwind is fix at 60 seconds after the abeam threshold position.

Note: *The formulas do not take the wind into account and are therefore rules of thumb.*

8 Abbreviations

This section contains abbreviations and shortcuts as used in this document.

A/C Aircraft

A/D Aerodrome

A/P Airport

ADF Automatic Direction Finder

AGL Above Ground Level

ALT Altitude

AoA Angle of Attack

AoL Angle of Lead

AOM Aircraft Operation Manual

APPR Approach

APV Approach with Vertical Guidance

ASR Aerodrome Surveillance Radar

ATC Air Traffic Control

AZ Arizona

BOD Bottom of Descent

BW Bundeswehr

CAT Category

CB Cumulo Nimbus

CDFA Continuous Descent Final Approach

CDI Course Deviation Indicator

CEO Chief Executive Officer

CM Crew Member

COM Communication Device (Radio)

CRS Course

CWC Cross Wind Component

DA Drift Angle

D_e Drift expected

DH Decision Height

DME Distance Measuring Equipment

DoL Distance of Lead

d_{TOD} Distance to Top of Descent

FAF Final Approach Fix

FAP Final Approach Point

FGC Flight Guidance Computer

FIX Fix point

FL Flight Level

FNPT Flight Navigation Procedure Trainer

fpm Feet per Minute

FSD Full Scale Deflection

ft Feet

G Bearing Change Angle

GCA Ground Controlled Approach

GLS GNSS Landing System

GNSS Global Navigation Satellite System

GP Glide Path

GPS Global Positioning System

GS Ground Speed

h Hour

HDG Heading

HSD Half Scale Deflection

HSI Horizontal Situation Indicator

HWC Headwind Component

i Interception Angle

IAA Initial Approach Altitude

IAC Instrument Approach and Landing Chart

IAF Initial Approach Fix

IAS Indicated Air Speed

ICAO International Civil Aviation Organization

IF Intermediate Fix

IFP Instrument Flight Procedure

IFR Instrument Flight Rule

ILS Instrument Landing System

IM Inner Marker

IP Instructor Pilot

kt Knot

LFT Lufthansa Flight Training GmbH

LH Lufthansa

LIDO Lufthansa Integrated Dispatch Operations

LNAV Lateral Navigation

LOP Line

LP Localizer Performance

LPV Localizer Performance with Vertical Guidance

LR Leading Radial

M Mach Number

m Meter

MAP Missed Approach Point

MB Magnetic Bering

MC Magnetic Course

MDA Minimum Descent Altitude

MDH Minimum Descent Height

MEA Minimum Enroute Altitude

MGA Minimum Grid Altitude

MH Magnetic Heading

MHA Minimum Holding Altitude

min Minute

MLS Microwave Landing System

MM Middle Marker

MSA Minimum Safe Altitude

NAVAID Radio Aid for Navigation

NDB Non-Directional Radio Beacon

NM Nautical Mile

OM Outer Marker

OM-A Operation Manual A (Rules of Flight)

OM-B Operation Manual B (AOM)

OM-C Operation Manual C (Route Manual)

PAR Precision Approach Radar

PF Pilot Flying

PNF Pilot Not Flying

QDM MB to Station

QDR MB from Station

RB Relative Bearing

RFC Radio Facility Chart

RMI Radio Magnetic Indicator

RNAV Area Navigation

RNP Required Navigation Performance

RoC Rate of Climb

RoD Rate of Descent

RoT Rate of Turn

RVR Runway Visual Range

RWY Runway

s Second

sec Second

SID Standard Instrument Departure

SPD Speed

SRA Surveillance Radar Approach

SRE Surveillance Radar Equipment

SRT Standard Rate Turn

STAR Standard Arrival Route

TAS True air Speed

TC True Course

t_D Time Distance

TDZE Touch Down Zone Elevation

TH True Heading

TKE Track Angle Error

TOC Top of Climb

TOD Top of Descent

TRK Track

TSE Total System Error

TWC Tailwind Component

V Wind Speed

VDP Visual Descent Point

VHF Very High Frequency

VIS Visibility

VNAV Vertical Navigation

VOR VHF Omnidirectional Radio Ranging

W Wind Direction

wa Wind Angle

WC Wind Component

WCA Wind Correction Angle

WP Waypoint

XTK Cross Track Error

ZofF Zone of Flexibility

9 Tables

10 References

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11 Index

Proposed Corrections Deletions and Changes to the Procedures

Ich möchte folgende Verfahren ändern bzw löschen:

Time Corrections

1. ALLE Zeitkorrekturen nach der 1min-Tabelle. Bei längeren Zeiten sinngemäß anpassen.

2. Bei Crosswind KEINE Zeitkorrektur, auch kein Adjustment!

Tracking

1. Tracken: Save Sector immer innerhalb halben Vollausschlags, statt 1 Dot.

Interceptions

1. Nahbereich-Interceptions mit 30^o und 45^o sind gleichwertig.

2. LH Interception outbound wird wie BW Interception outbound geflogen und nicht nach der Formel.

3. AoL nur bei Interception Angles $> 45^o$, sonst nicht.

Holdings

1. Special Direct Entry: vorheriges MH für 20 sec weiterfliegen, statt auf $MH_\perp$ zu törnen. (Zuviel Getörns!) Ein Groundtrack von 20^o off zur Centerline macht eine Verkürzung von nur 6% aus ($cos(20^o = 0.94$).

2. Verbesserung der Definition: Start Timer Parallel entry: wenn auf $MH_{outbound}$.

3. Beim Parallel Entry nur noch 45^o-Interceptions auf Inbound Course. Timer Start wenn auf MH.

4. Beim Parallel Entry Timer Start, wenn auf MH.

Procedure Turns

1. 45^o-P/T wird ersatzlos gestrichen. Auch wenn beim Circling jetzt ein 45^o-Entry Standard ist - das ist was anderes. Wenn er doch geflogen werden soll, dann mit verbesserter Zeitkorrektur auf dem 45^o CRS.

2. Der 45^o-P/T benötigt Führung durch ein Navaid, um den Inbound Course intercepten zu können, der 80^o-P/T nicht.

3. 80^o Procedure Turn ist besser und schneller als alle anderen Turns!

4. Zeitkorrektur beim (time based) Base Turn immer, nach Tabelle.

5. DME-Arc Regeln angepaßt.