5th International Conference on Research in Air Transportation

Instrument Flight Procedures

Xavier Prats
Technical University of Catalonia – Barcelona Tech

xavier.prats@upc.edu
Introduction

Flight Rules

**VFR: Visual Flight Rules**
- Visibility better than (5-)8 km (Special VFR)
- ATS flight plan optional (in some states...)
- Fewer training/equipage required

**IFR: Instrumental Flight Rules**
- Use of Radionavigation means
- ATS flight plan must be filed AND approved
- More training/equipage is required

Flight procedures:
ICAO Document 8168
Procedures for Air Navigation Services:
Aircraft Operations
PANS-OPS
Introduction
Introduction

VFR chart
Introduction

IFR chart
Introduction

Instrument flight procedures

• Provide flight guidance under IMC
• Provide obstacle clearance
• Provide separation with other procedures
• Help in managing air traffic
• Ensure proper radionavigation coverage

IMC: Instrument Meteorological Conditions
Introduction

Air Traffic Management Example

BAY TRACON
Traffic Flow
South East Plan
Introduction

Air Traffic Management Example

BAY TRACON
Traffic Flow
South West Plan
Contents of the presentation

1 - Radionavigation means
2 - Flight procedures
3 - Airspace management
4 - Instrument approach procedures
Radionavigation
Radionavigation

Non Directional Beacon (NDB)

- Radio transmitter at a known location
- 190 kHz – 1750 kHz (ICAO Annex 10)
  - 280-530 kHz (Europe) 190-530 kHz (North America)
- Onboard Receiver: Automatic Direction Finder (ADF)
- Sensitive to meteorological effects, terrain, aircraft bank...
VHF Onmidirectional Range (VOR)

- Radio transmitter at a known location
- 108 MHz – 117.95 MHz (ICAO Annex 10)
- Onboard Indicators: Omni Bearing Indicator (OBI), Horizontal Situation Indicator (HSI), Radio Magnetic Indicator (RMI)
- Reception range: 25NM – 200 NM
- Signal more robust than NDB
Radionavigation

Distance Measurement Equipment (DME)

- Radio transponder at a known location
- 1025 – 1150 MHz (airplane interrogator)
- 962 – 1150 MHz (ground transponder)
- Band with 126 channels for interrogation and 126 for replies
- Usually collocated with a VOR station
- Collocated also with ILS (and NDB)

PU Ch 38 X (110.1)
Radionavigation

Instrument Landing System (ILS)

- Localizer (LLZ): 108 – 112 MHz
- Glide slope (GS): 329 – 335 MHz
- Markers: 75 MHz
  - Outer Marker (OM), Medium Marker (MM), Inner marker (IM)
Radionavigation

- VOR
- DME
- NDB
- LOC
- GP

ICRAT 2012 - Tutorial
Instrument Flight Procedures – 15

Xavier Prats
May 22nd 2012
Radionavigation

Other radionavigation means:

- **Locator (L):** Same technology as NDB, but reduced coverage

- **Tactical AirNavigation (TACAN):** “Military version” of VOR+DME

- **Inertial Navigation/Reference Systems (INS/IRS)**

- **Microwave Landing System (MLS)**
  
  Azimuth + Elevation angle (glide path)
Radionavigation

Other radionavigation means:

- **LORAN-C**: Hyperbolic system
- **Direction Finder (DF)** *
- **Surveillance Radar Equipment (SRE)** *
- **Precision Approach Radar (PAR)** *

* Typically surveillance systems, but can be used to issue navigational information to the aircraft crew
Global Navigation Satellite Systems (GNSS)

- Global Constellations
  - GPS: Global Positioning System
  - GLONASS: Global'naya Navigatsionnaya Sputnikovaya Sistema
  - [GALILEO, COMPASS, IRNSS...]

- Augmentation Systems
  - ABAS: Aircraft Based Augmentation Systems
  - GBAS: Ground Based Augmentation Systems
  - SBAS: Satellite Based Augmentation Systems
Global Positioning

GPS Accuracy: 10 to 100m

Availability?

INTEGRITY!!??

[x,y,z,Δt]
Radionavigation

GNSS Augmentation

Example: SBAS (Satellite Based Augmentation System)
GNSS Integrity

IMAL: Integrity monitoring alarm limit
HAL: Horizontal Alert Limit
VAL: Vertical Alert Limit
Radionavigation

GNSS Integrity

Example: Vertical Alert Limit

MI: Misleading Information

HMI: Hazardous Misleading Information
## GNSS SARPS – ICAO Annex 10 Vol I

<table>
<thead>
<tr>
<th></th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Continuity</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
<td>Vertical</td>
<td>Risk</td>
<td>Alert limits</td>
</tr>
<tr>
<td>En-route</td>
<td>3.7 km</td>
<td>N/A</td>
<td>$10^{-7}$/h</td>
<td>HAL 7.4 km</td>
</tr>
<tr>
<td>En-route, terminal</td>
<td>0.74 km</td>
<td>N/A</td>
<td>$10^{-7}$/h</td>
<td>HAL 3.7 to HAL 1.85</td>
</tr>
<tr>
<td>Initial app.,</td>
<td>220 m</td>
<td>N/A</td>
<td>$10^{-7}$/h</td>
<td>HAL 556 m</td>
</tr>
<tr>
<td>Intermediate app.,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-precision app.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Departure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APV-I</td>
<td>220 m</td>
<td>20 m</td>
<td>2x$10^{-7}$/approach</td>
<td>HAL 40 m VAL 50 m</td>
</tr>
<tr>
<td>APV-II</td>
<td>16 m</td>
<td>8 m</td>
<td>2x$10^{-7}$/approach</td>
<td>HAL 40 m VAL 20 m</td>
</tr>
<tr>
<td>CAT-I</td>
<td>16 m</td>
<td>6 to 4 m</td>
<td>2x$10^{-7}$/approach</td>
<td>HAL 40 m VAL 15 m to 10 m</td>
</tr>
</tbody>
</table>
RNAV Concept

RNAV = Area Navigation

A **method of navigation** which permits aircraft operation on **any desired flight path within the coverage** of station-referenced navigation aids, or a combination of these.

A **method of navigation** using flight tracks **joining any two points without** the need for the **overfly of specific ground facilities**.
RNAV = Area Navigation

RNAV is NOT free flight!
RNAV capable system

DME/DME
VOR/DME
GNSS (with augmentation system)
INS/IRS (Loran C)
FMS + DB

Aircraft Position
RNAV positioning

RNAV System

VOR/DME

- Automatic VOR/DME selection
- Automatic position computation
RNAV positioning

RNAV System

DME/DME

- Automatic DME selection
- Automatic position computation
- Good geometry required
RNAV positioning

RNAV System

GNSS, INS/IRS, (Loran C)

- GNSS: Good geometry required

Coordinates:
- 41°31'15"N, 00°26'35"E
- 41°01'12"N, 00°26'75"E
- 41°23'22"N, 00°52'41"E
RNAV positioning

Good geometry?

DME/DME

\[ a = \text{intersection angle} \]

\[ 30 < a < 150 \]
RNAV positioning

Good geometry?

GNSS

DOP (Dilution of precision):

# Satellites in view
Geometry
Satellite outage
RNAV positioning

The RNAV system:

● Selects the best source of navigation if more than one is available.

● Always flies to the next waypoint and provides guidance data to the autopilot system.

● Provides guidance data to the flight director in order to fly manually.

● Express waypoints in WGS84 coordinates
RNAV advantages

RNAV navigation allows:

- More direct routes (flight time reduction)
- Less fuel consumption
- Delay reduction (more routes, no bottlenecks)
- Noise reduction
- Less track dispersion
RNAV advantages

Conventional Navigation

RNAV Navigation
Contents of the presentation

1 - Radionavigation means
2 - Flight procedures
3 - Airspace management
4 - Instrument approach procedures
Flight Phases and Procedures

Top of Climb (TOC, T/C) → Top of Descent (TOD, T/D)

Climb phase ≠ Departure phase
Cruise phase ≠ En-route phase
Descent phase ≠ Arrival/App phase

Aircraft Performance
Air Traffic Management

ICRAT 2012 - Tutorial
Instrument Flight Procedures – 36
Flight procedures

Departure Procedures

Standard Instrumental Departures (SID)
Flight procedures

Departure Procedures

Omnidirectional Departures
Flight procedures

En-route procedures

Airways
Arrival Procedures

Standard Terminal Arrival Routes (STAR)
Flight procedures

Arrival Procedures

Omnidirectional Arrivals

Millville MSA

Manchester MSA
Flight procedures

Approach Procedures
Conventional Procedures

FIXES

- Facilities
- Intersections
- Timing
Conventional Procedures

FIXES vs. POINTS

FIX

Point
Conventional Procedures

**Named points/fixes:**
- IAF → Initial Approach Fix
- IF → Intermediate Fix
- FAF → Final Approach Fix
- FAP → Final Approach Point
- MAPt → Missed Approach Point
Conventional Procedures

LEGS

- VOR radial
- Dead reckoning
- NDB course
- ILS Localizer / MLS azimuth
- DME arc
Conventional Procedures

- NDB course
- VOR radial
- DME arc

Guided Path
Non-guided Path
RNAV procedures

- Fly-Over waypoints

- Fly-by waypoints

Named waypoints:

- IAF: Initial Approach Fix
- IF: Intermediate Fix
- FAF: Final Approach Fix
- MAPt: Missed Approach Point
- MAHF: Missed Approach Holding Fix

[NOTE: IAWP, IWP, FAWP, MAWP removed in amendment 12, ICAO Doc 8168]
RNAV procedures

Guided Path

Non-guided Path

Fly-over

No lead radials!!

Fly-by
RNAV Path and Terminators

- Transform procedures into coded flight path
- How to navigate from a starting point/location to a terminating point/condition

Example:
TF: Track between Fixes
RNAV Path and Terminators

- Transform procedures into coded flight path
- How to navigate from a starting point/location to a terminating point/condition

Example:
DF: Direct to a Fix

Guided Path
Non-guided Path
RNAV Path and Terminators

- Transform **procedures** into **coded** flight path
- How to navigate from a starting point/location to a **terminating** point/condition

Example:
CF: Course to a Fix

Guided Path
Non-guided Path
RNAV Path and Terminators

Path and Terminator

- Specification: ARINC 424 standard
- Set of two alphabetic characters
- Instructions to navigate to a specific point or a terminating condition
- 23 different path terminators
- Procedures are transformed into a coded flight path

With RNAV the aircraft flies according to the database not the charts!!!
# RNAV Path and Terminators

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF</td>
<td>Initial Fix</td>
</tr>
<tr>
<td>DF</td>
<td>Direct to fix</td>
</tr>
<tr>
<td>TF</td>
<td>Track between fixes</td>
</tr>
<tr>
<td>RF</td>
<td>Radius to fix</td>
</tr>
<tr>
<td>CF</td>
<td>Course to fix</td>
</tr>
<tr>
<td>CD</td>
<td>Course to DME arc</td>
</tr>
<tr>
<td>CR</td>
<td>Course to VOR radial</td>
</tr>
<tr>
<td>CA</td>
<td>Course to altitude</td>
</tr>
<tr>
<td>CI</td>
<td>Course to intercept next leg</td>
</tr>
<tr>
<td>HF</td>
<td>Hold/racetrack to fix</td>
</tr>
<tr>
<td>HA</td>
<td>Hold/racetrack to altitude</td>
</tr>
<tr>
<td>HM</td>
<td>Hold/racetrack for manual termination (clearance)</td>
</tr>
<tr>
<td>PI</td>
<td>Procedure turn to intercept next leg</td>
</tr>
<tr>
<td>FC</td>
<td>From fix to a distance</td>
</tr>
<tr>
<td>FD</td>
<td>From fix to a DME arc</td>
</tr>
<tr>
<td>FA</td>
<td>From fix to an altitude</td>
</tr>
<tr>
<td>FM</td>
<td>From fix to manual termination</td>
</tr>
<tr>
<td>AF</td>
<td>DME arc to fix</td>
</tr>
<tr>
<td>VD</td>
<td>Heading to DME arc</td>
</tr>
<tr>
<td>VA</td>
<td>Heading to altitude (climb)</td>
</tr>
<tr>
<td>VM</td>
<td>Heading to manual termination (vectors)</td>
</tr>
<tr>
<td>VI</td>
<td>Heading to intercept next leg</td>
</tr>
<tr>
<td>VR</td>
<td>Heading to VOR Radial</td>
</tr>
</tbody>
</table>

RNAV path terminators. Others used to code conventional procedures.
Contents of the presentation

1 - Radionavigation means
2 - Flight procedures
3 - Airspace management
4 - Instrument approach procedures
Controlled Airspace

Types of controlled Airspace

- AWY: Airway
- CTR: Control Zone  (from surface level)
- CTA: Control Area
- TMA: Terminal Maneuvering Area
- ATZ*: Aerodrome Traffic Zone  (usually 1500' and 5NM)

* The ATZ can be non-controlled or with traffic information
Controlled Airspace

http://www.youtube.com/watch?NR=1&v=8X2KkNQWobw
Controlled Airspace

Example: Controlled airspace in Spain
Controlled Airspace
Example: high altitude sectors in the continental USA
Airspace Design

Example: high altitude routes in the continental USA
Airspace Design

Example 1: Barcelona SIDs and STARs strategic deconfliction
Airspace Design

Example 2: Palma de Mallorca SIDs and STARs strategic deconfliction

SIDs: Maintain 6000 ft

SIDs: Maintain 4000 ft
Airspace Design

Example 3: Heathrow strategic deconfliction

AIRCRAFT STACKING SYSTEM

When the aircraft leave the stack they are approx 2.5 - 7 miles apart.

Aircraft, taking off reach a maximum of 6,000ft.

6 to a stack average

15,000ft

7,000ft

1,000ft

LOW APPROACH FLIGHT PATHS

ENGLAND

BOVINGDON

LAMBOURNE

GREATER LONDON

OCKHAM

BIGGIN

Heathrow Airport

SOURCE: BAA
Airspace Design

Example 4: Heathrow new ERAT project (www.erat.aero)

ERAT Heart 1a concept
http://youtu.be/e0C7SR1gSs0
Contents of the presentation

1 - Radionavigation means
2 - Flight procedures
3 - Airspace management
4 - Instrument approach procedures
I FR approaches

Conventional Radionavigation

Departure
En-Route
Arrival
Approach

Final Approach segment

Non Precision Approach (NPA)

Precision Approach (PA)

VOR: VHF Omnidirectional Range
DME: Distance Measurement Equipment
NDB: Non Directional Beacon
SRE: Secondary Radar Equipment

DF: Direction Finder
L: Locator
LOC (or LLZ): Localizer (ILS)
MLS: Microwave Landing System

VOR (+DME) DF
NDB LOC SRE
L MLS azimuth

VOR: VHF Omnidirectional Range
DME: Distance Measurement Equipment
NDB: Non Directional Beacon
SRE: Secondary Radar Equipment

DF: Direction Finder
L: Locator
LOC (or LLZ): Localizer (ILS)
MLS: Microwave Landing System

ICRAT 2012 - Tutorial
Instrument Flight Procedures – 68

Xavier Prats
May 22nd 2012
IFR approaches

RNAV
Radionavigation

Departure
En-Route
Arrival
Approach

Final Approach segment

LNAV

2D

Non Precision Approach (NPA)

LNAV

LP

2D

Precision Approach (PA)

GLS

LNAV/VNAV

LPV

3D

APproach with Vertical guidance (APV)

RNAV: Area Navigation
LNAV: Lateral Navigation
LP: Localizer Performance
GLS: GNSS Landing System
LNAV/VNAV: Lateral Navigation / Vertical Navigation
LPV: Localizer Performance with Vertical guidance
IFR approaches

RNAV Non Precision Approach (NPA)

- **LNAV (Lateral Navigation):** DME/DME, VOR/DME, INS/IRS, ABAS, GPS,…

- **LP (Localizer performance):** SBAS not able to provide vertical guidance.

INS: Inertial Navigation System
IRS: Inertial Reference System
ABAS: Airborne Based Augmentation System
SBAS: Satellite Based Augmentation System
IFR approaches

RNAV Approach with Vertical Guidance (APV)

• LNAV/VNAV (Lateral Navigation/Vertical Navigation) (APV BaroVnav): SBAS class 2, Baro-VNAV system.

• LPV (Localizer Performance with Vertical guidance) (APV SBAS): SBAS class 3-4.

RNAV Precision Approach (PA)

• GLS (GNSS Landing System): GBAS, dual frequency SBAS, ...
IFR approaches

Approach procedures designed for different Aircraft Categories*:

- **Category A:** $\text{Vat} < 169 \text{ km/h}$
- **Category B:** $169 \text{ km/h} < \text{Vat} < 224 \text{ km/h}$
- **Category C:** $224 \text{ km/h} < \text{Vat} < 261 \text{ km/h}$
- **Category D:** $261 \text{ km/h} < \text{Vat} < 307 \text{ km/h}$
- **Category E:** $307 \text{ km/h} < \text{Vat} < 391 \text{ km/h}$
- **Category H:** Helicopters

Airspeed at Threshold (IAS) $\Rightarrow \text{Vat} = 1.3V_{s1g}$ at MLW

IAS: Indicated AirSpeed
MLW: Maximum Landing Weight

* ICAO Doc. 8168 PANS-OPS Vol-I
Approach procedures designed for different Aircraft Categories*:

Category A: Cessna 172, Piper PA28, Beech Baron,...
Category B: ATR72, Falcon 10,...
Category C: Airbus A320, Boeing 737, MD83,...
Category D: Airbus A340, Boeing 747, DC10,...
Category E: Concorde
Category H: Helicopters

* ICAO Doc. 8168 PANS-OPS Vol-I
IFR approaches

Approach procedure segments:

1- Initial Segment
   Allows the aircraft to descend and align with the runway

2- Intermediate Segment**
   Allows the aircraft to transition to the landing configuration (speed, flap/slats...)

3- Final Segment*
   Allows a safe descend to the runway for landing

4- Missed Approach Segment*
   Allows a safe climb in case of aborted landing

* Mandatory segments in ALL type of approaches
** Mandatory segment only in PA and APV approaches
IFR approaches

Types of approaches

Straight-in approach
If final approach track moved 30 deg or less from runway centerline AND final descent gradient within specified limits*

Circling approach (circle to land)
If not Straight-in approach
- “free” visual manoeuvering (circling)
- visual manoeuvering using prescribed tracks

* See ICAO Doc. 8168 PANS-OPS Vol-II
IFR approaches

Types of approaches

Non Precision Approach (NPA)
- Lateral Guidance
- MDA/H: Minimum Descent Altitude/Height
- MAPt: Missed Approach Point

Precision Approach (PA) and Approach with Vertical Guidance (APV)
- Lateral **AND** Vertical Guidance
- DA/H: Decision Altitude/Height
- Altitude cross-check with marker beacons and/or DME
IFR approaches

Non Precision Approach (NPA)

FAF (or end of turn)

Minimum Descent Altitude/Height (MDA/H)

Non-guided descent

Missed approach

Missed Approach Point (MAPt)

Visual Landing
IFR approaches

Precision Approach (PA) or Approach with Vertical Guidance (APV)

Decision Altitude/Height (DA/H)

FAP

Guided descent

Marker beacon

Missed approach

Visual Landing
IFR approaches

Example chart: PAU PYRENEES

• Type(s) of aircraft?
• Type(s) of approach(es)? (ILS, LPV, NDB, LOC, VOR, ...)
• For each approach:
  Straight-in, circling or visual prescribed tracks?
  Precision Approach, Non Precision Approach, APV?
  DA(H) or MDA(H)?

French nomenclature:
MVL (Manoeuvre a Vue Libre) = Visual circling
MVI (Manoeuvre a Vue Imposée) = Visual prescribed tracks
**Initial Segment**

- **Start:** IAF
- **End:** IF or FAF or end of turn

**Free (for the procedure designer!) trajectories:**
- Straight with track guidance
- Straight dead reckoning
- Curved with track guidance (DME arc, RNAV RF leg)

**Pre-defined trajectories:**
Used if initial turn exceeds 120° and/or to provide room for extra descent and/or to increase final segment length
- Reversal procedure (or procedure turn)
- Racetrack procedure
Reversal Procedure: 45°/180° procedure turn

Guided Path

Non-guided Path

Intersection or timing (T)

Facility

End of turn

1', CAT A/B
1'15", CAT C/D/E

R-233
Initial Segment

Reversal Procedure: 80°/260° procedure turn

Guided Path

Non-guided Path

Intersection or timing (T)

End of turn

Facility

T
Initial Segment

Reversal Procedure: Base turn (tear drop)

Guided Path

Non-guided Path

Intersection or timing ($T$)

End of turn

Facility
Arrivals outside the direct entry sector must integrate a hold (usually defined above the facility) first prior to the reversal procedure.
Racetrack Procedure:

Guided Path

Non-guided Path

A Racetrack IS NOT a holding procedure!!

Intersection or timing (T)

Same holding procedures entry and turn principles apply

Facility

End of turn
Intermediate Segment

- **Start:** IF or end of turn
- **End:** - Non Precision Approaches: FAF
  - Precision Approaches and APV: FAP

- Horizontal (constant altitude) and straight segment *
- Segment with track guidance
- Minimum length: 30” at initial segment speed
- Mandatory segment for Precision Approaches and APV

* Some exceptions might apply. See ICAO Doc. 8168 PANS-OPS Vol-II
Final Segment

- **Start:**
  - Non Precision Approaches: FAF or end of turn
  - Precision Approaches and APV: FAP
- **End:**
  - Non Precision Approaches: MAPt
  - Precision Approaches and APV: when reaching DA/H

- MAPt definition:
  - Overflying a facility
  - Intersection
  - DME distance or timing from a FIX/Facility
Obstacle clearance Altitude/Height (OCA/H)
The lowest altitude/height used in establishing compliance with appropriate obstacle clearance criteria.

Minimum Descent Altitude/Height (MDA/H)
Specified altitude/height in a non-precision approach or a circling approach below which descent must not be made without the required visual reference.

Decision Altitude/Height (DA/H)
Specified altitude/height in a precision approach or APV at which a missed approach must be initiated if the required visual reference to continue the approach has not been established.
Final Segment

Obstacle clearance Altitude/Height (OCA/H)
The state must determine and publish it

Minimum Descent Altitude/Height (MDA/H) and Decision Altitude/Height (DA/H)
The state may publish a lower bound* for the (M)DA/H and/or RVR. The operator must establish (M)DA/H and RVR or Visibility (airport minima) and the state must approve them.

* Also known as the “minimum-minimum”

RVR: Runway Visual Range
**Final Segment**

### Perpinyà
- **ILS/LLZ RWY 33**
- **French**
- **DGAC**

### Granada
- **ILS RWY 09**
- **AENA**

#### Instrument Flight Procedures – 90

**ICRAT 2012 - Tutorial**

**Instrument Flight Procedures – 90**

Xavier Prats

**May 22nd 2012**
### Final Segment

**Long Beach (CA) ILS/LOC RWY 30**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-ILS 30</td>
<td>250/18</td>
<td>212 (200-1/2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-LOC 30</td>
<td>520/24</td>
<td>482 (500-1/2)</td>
<td>520/40</td>
<td>482 (500-3/4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>520/50</td>
<td>482 (500-1)</td>
</tr>
<tr>
<td>CIRCLING</td>
<td>880-1</td>
<td>880-1/4</td>
<td>880-2 1/2</td>
<td>880-2 3/4</td>
</tr>
<tr>
<td></td>
<td>820 (900-1)</td>
<td>820 (900-1/4)</td>
<td>820 (900-2 1/2)</td>
<td>820 (900-2 3/4)</td>
</tr>
</tbody>
</table>

**DA/RVR**

* In hundreds of feet (if RVR) or statute miles (if Visibility)

Different RVRs (or Visibility) as a function of the airport lighting system status.
Final Segment

MDA or DA
MDH or DH

MDA/H or DA/H
Lower bound

OCA
OCH

Operational Safety Margin

Obstacle clearance Safety Margin

Highest applicable Obstacle

Threshold elevation

Mean Sea Level

* ICAO Doc. 8168 PANS-OPS Vol-II
** ICAO Annex 6: Operation of Aircraft.
Final Segment

Vertical performance

Conventional Approaches

Precision Approaches (PA)

CAT I
CAT II
CAT III A
CAT III B
CAT III C

RNAV Approaches

Approaches with Vertical Guidance (APV)

APV I
(APV II)*

Precision Approaches (PA)

CAT I
(CAT II)*
(CAT III A)*
(CAT III B )*
(CAT III C )*

* No criteria published (yet)
## Navigation system requirements

### Example: GNSS SARPS (ICAO Annex 10 Vol 1)

<table>
<thead>
<tr>
<th></th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Continuity</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
<td>Vertical</td>
<td>Risk</td>
<td>Alert limits</td>
</tr>
<tr>
<td>En-route</td>
<td>3,7 km</td>
<td>N/A</td>
<td>10^-7 / h</td>
<td>HAL 7.4 km</td>
</tr>
<tr>
<td>En-route, terminal</td>
<td>0,74 km</td>
<td>N/A</td>
<td>10^-7 / h</td>
<td>HAL 3.7 to HAL 1.85</td>
</tr>
<tr>
<td>Initial app.,</td>
<td>220 m</td>
<td>N/A</td>
<td>10^-7 / h</td>
<td>HAL 556 m</td>
</tr>
<tr>
<td>Intermediate app.,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-precision app,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Departure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APV-I</td>
<td>220 m</td>
<td>20 m</td>
<td>2x10^-7 per approach</td>
<td>HAL 40 m VAL 50 m</td>
</tr>
<tr>
<td>APV-II</td>
<td>16 m</td>
<td>8 m</td>
<td>2x10^-7 per approach</td>
<td>HAL 40 m VAL 20 m</td>
</tr>
<tr>
<td>CAT-I</td>
<td>16 m</td>
<td>6 to 4 m</td>
<td>2x10^-7 per approach</td>
<td>HAL 40 m VAL 15 m to 10 m</td>
</tr>
</tbody>
</table>
Final Segment

Navigation system requirements

Example: GNSS Alarm limits

HAL: Horizontal Alert Limit. VAL: Vertical Alert Limit

Represents the containment of the uncertainty on aircraft position at $10^{-7}$ probability
## Approach “Minima-Minima“ (ICAO Annex 6)

<table>
<thead>
<tr>
<th>CAT I:</th>
<th>Decision Height (DH)</th>
<th>Visibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DH ≥ 200 ft</td>
<td>Visibility ≥ 800m or RVR ≥ 550m</td>
</tr>
<tr>
<td>CAT II*:</td>
<td>200 ft ≥ DH ≥ 100 ft</td>
<td>RVR ≥ 350 m</td>
</tr>
<tr>
<td>CAT III-A*:</td>
<td>100 ft ≥ DH ≥ 0 ft</td>
<td>RVR ≥ 200 m</td>
</tr>
<tr>
<td>CAT III-B*:</td>
<td>50 ft ≥ DH ≥ 0 ft</td>
<td>RVR ≥ 50 m</td>
</tr>
<tr>
<td>CAT III-C*:</td>
<td>No DH limitation</td>
<td>No RVR limitation</td>
</tr>
</tbody>
</table>

### Precision Approaches (PA)

- **APV I:** DH ≥ 250 ft, RVR ≥ 600m
- **APV II:** To be defined, To be defined

* Subject to operations and airworthiness evaluation (aircraft equipment, crew training, maintenance procedures, airport infrastructure, ATC training...)

RVR: Runway Visual Range
Missed Approach Segment

- **Start:**
  - Non Precision Approaches: MAPt
  - Precision Approaches and APV: when reaching DA/H

- **End:** When attaining the Minimum Obstacle Clearance (MOC) of the following segment

- After the Missed Approach, the aircraft will be able to:
  - Integrate into a holding pattern
  - Try the approach again
  - Resume navigation into the en-route airway structure
and... that’s all!

Thank you for your interest!