ENRI International Workshop on ATM/CNS (EIWAC)

Tokyo, Japan

Trajectory Management for Aircraft Noise Mitigation

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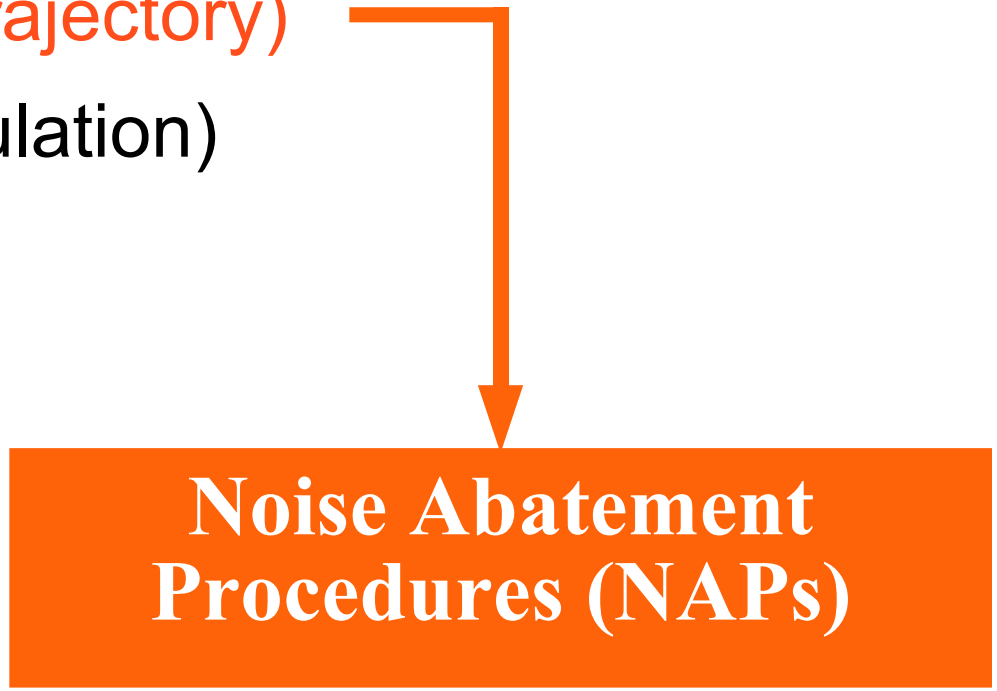
Introduction

- Increasing air traffic demand
- Increasing population around airports

Introduction

- Aircraft noise reduction
  - Source (aircraft)
  - Propagation (trajectory)
  - Receiver (population)



Noise Abatement Procedures

- Lateral Trajectory Management
  - Noise Preferential Routings (NPRs)

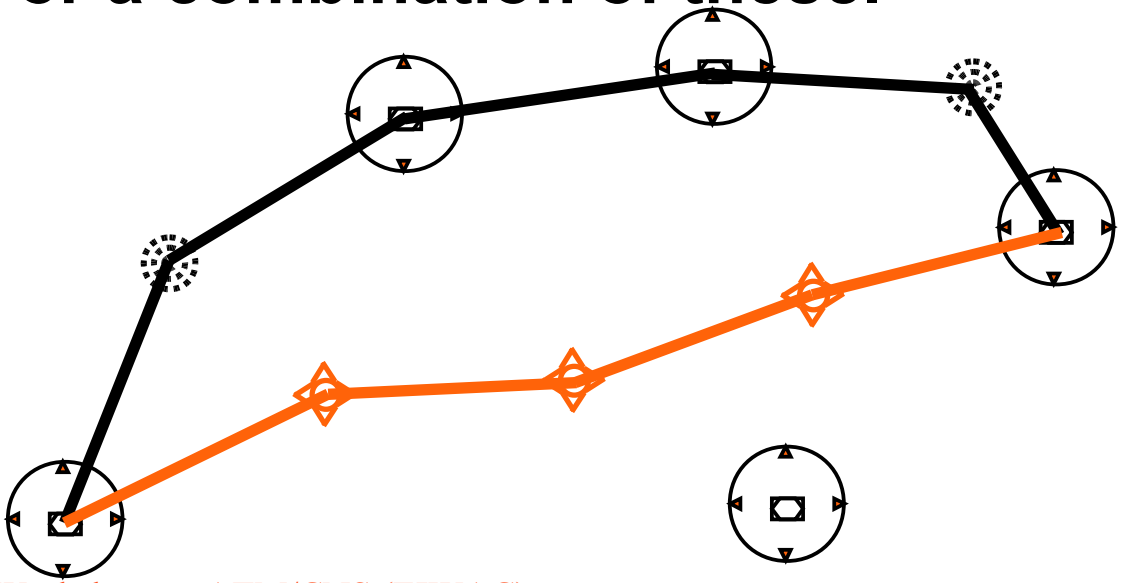
RNAV

- Vertical Trajectory Management
  - Arrival/approach strategies
  - Depart strategies

RNAV concept

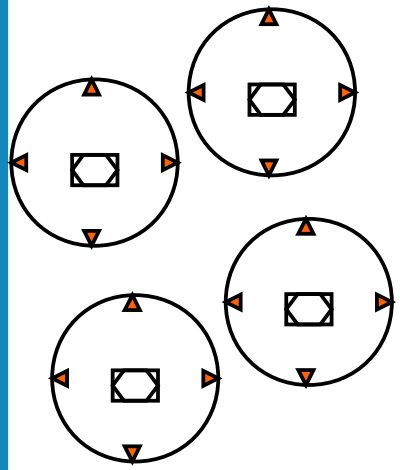
RNAV = Area Navigation

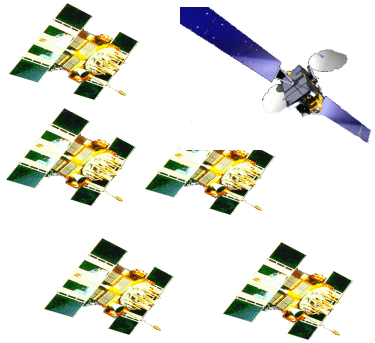
- **A method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids, or a combination of these.**



RNAV system

RNAV navigation





DME/DME

VOR/DME

GNSS

(with augmentation system)

INS/IRS

(Loran C)

FMS + DB

RNAV procedures

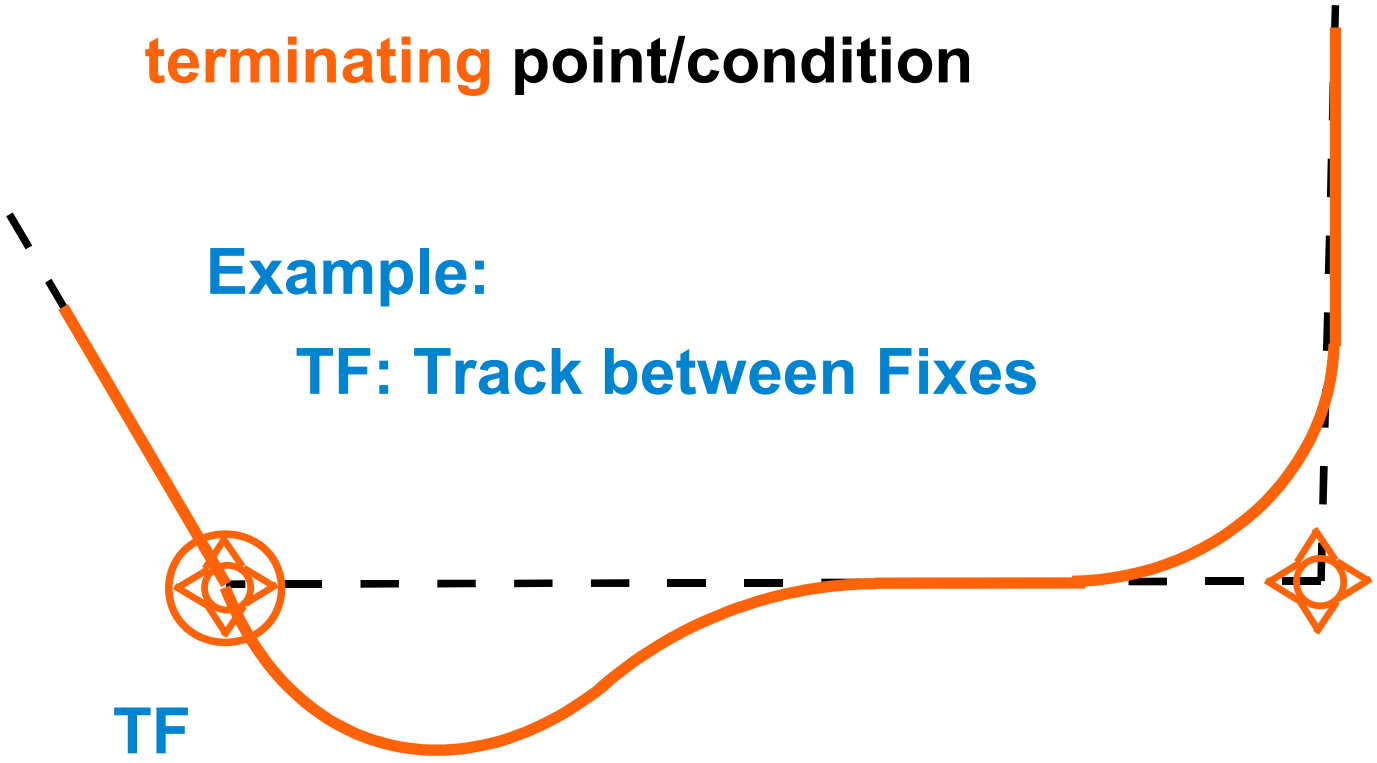
- Fly-Over waypoints
- Fly-by waypoints

With RNAV the aircraft flies according to the data base not the charts!!!

WAYPOINTS + PATH and TERINATORS

RNAV Path and Terminators

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



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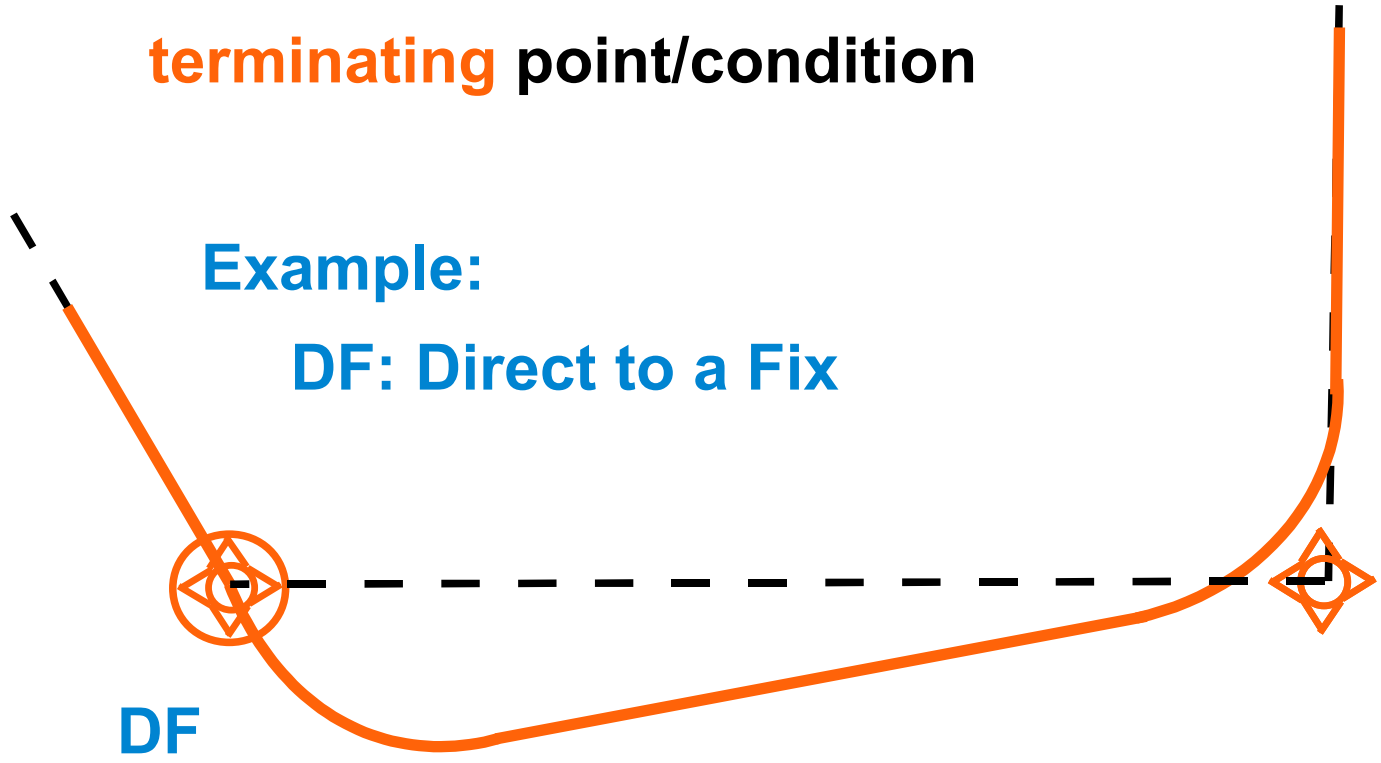

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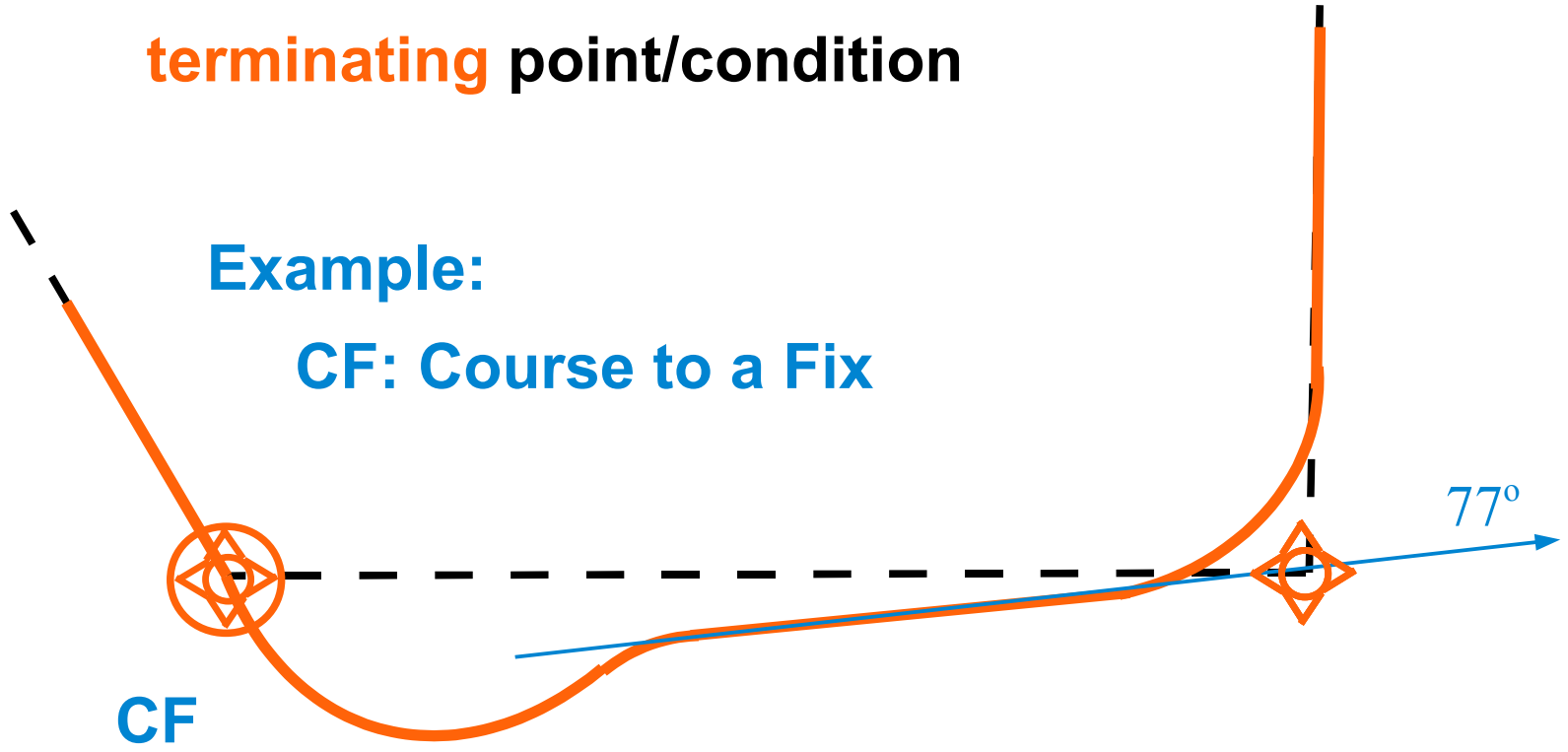

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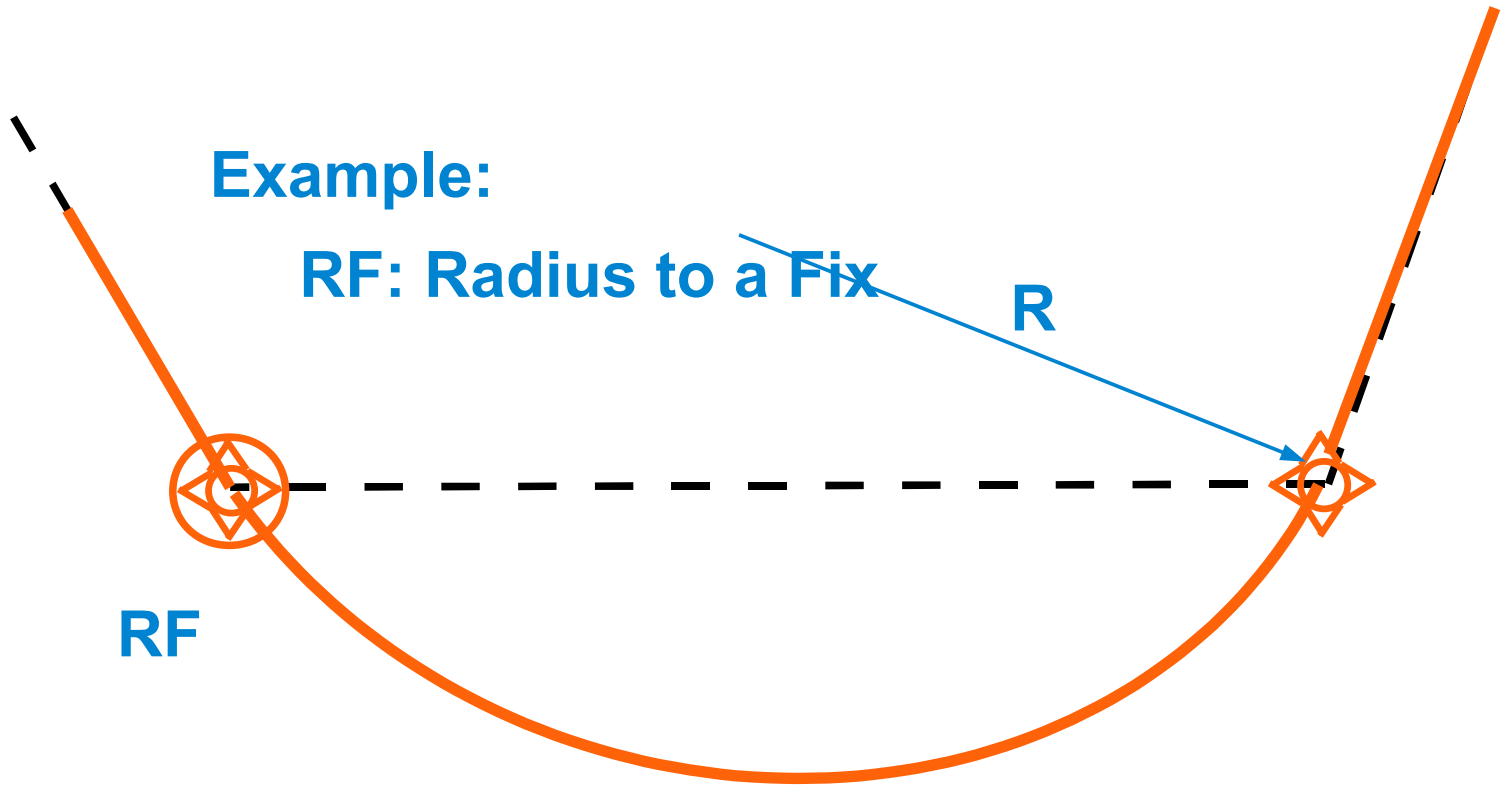
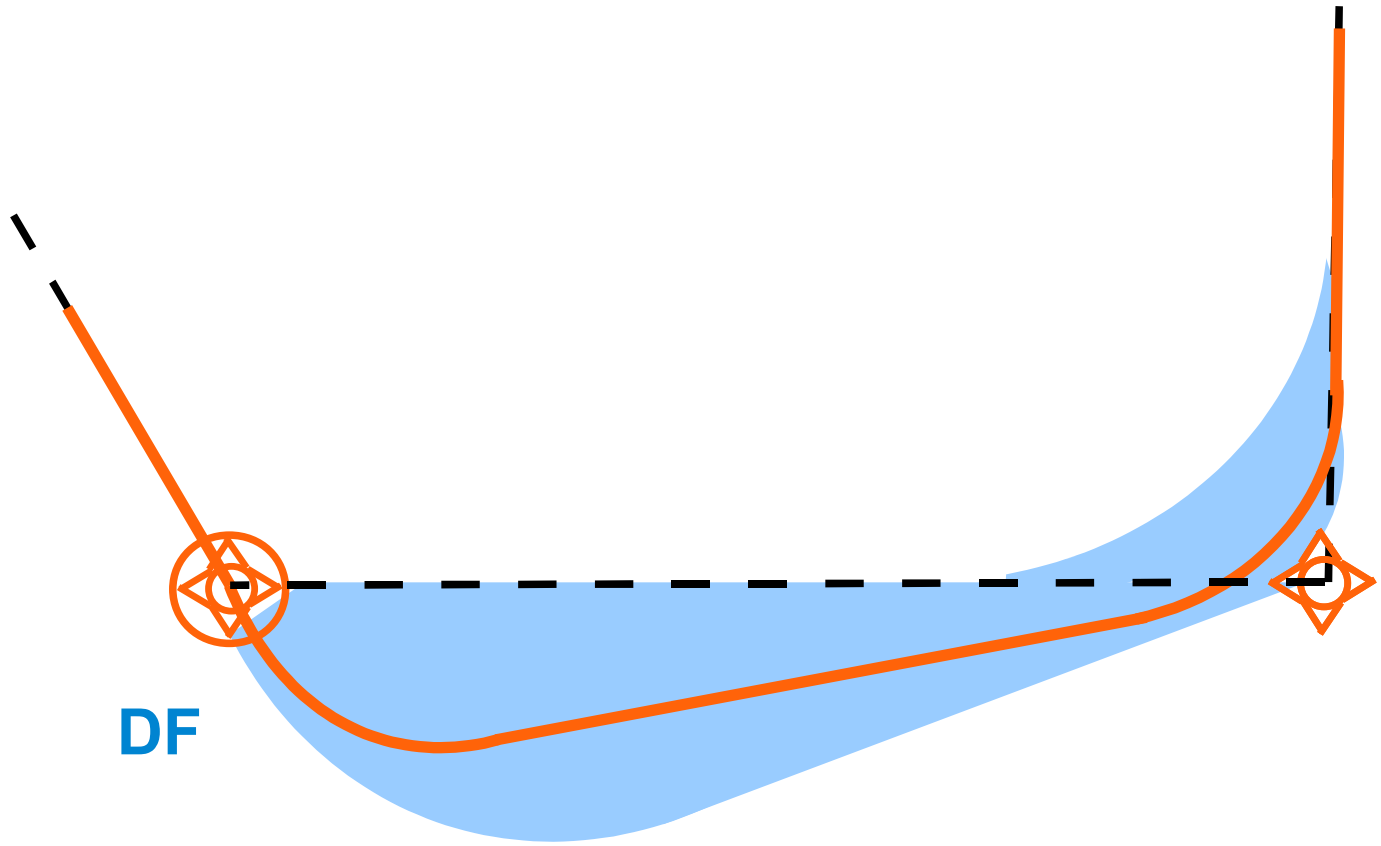


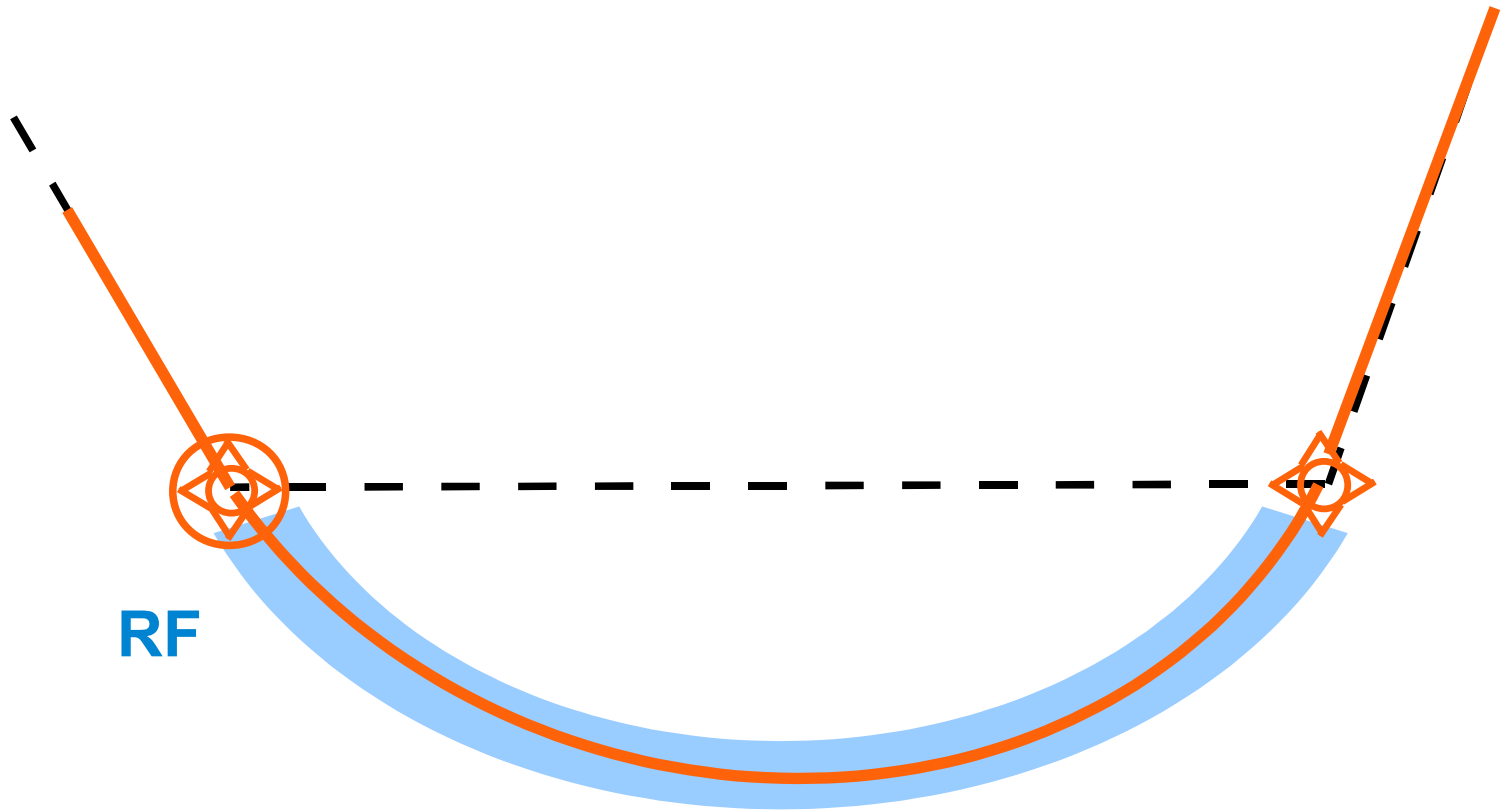
RNAV Path and Terminators

Track Dispersion



RNAV Path and Terminators

Track Dispersion

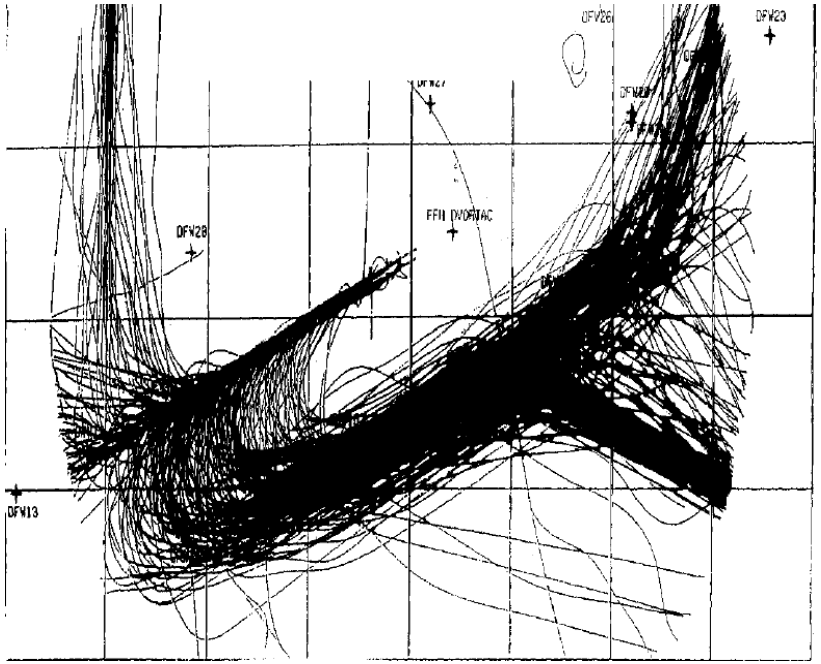


RNAV and NAPs

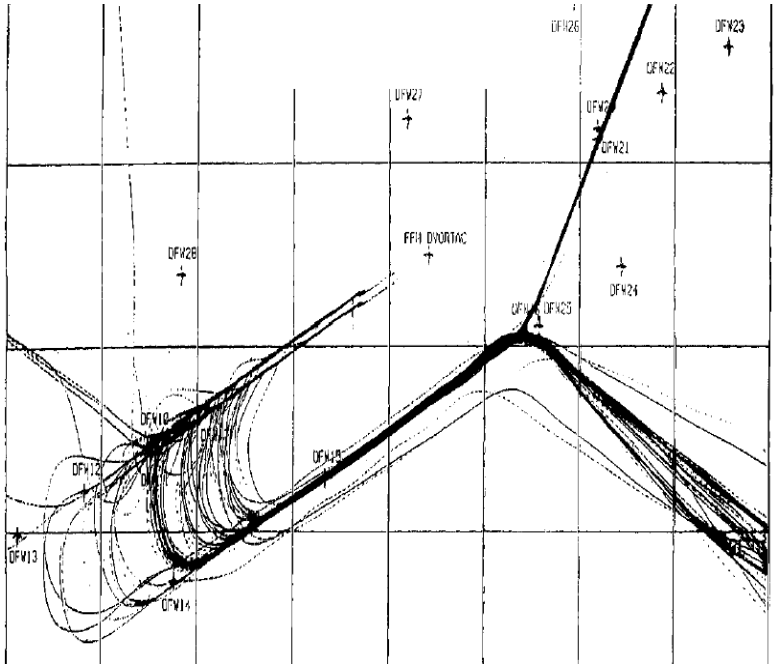
- RNAV is a major enabler for new and efficient noise abatement procedures.
- There is still some track dispersion in Fly-by or Fly-Over turns. Aircraft determine turn path on a "ad-hoc" basis (highly FMS dependant)
- Much higher accuracy throughout the turn when using Radius to Fix (RF) path terminator

RF leg:
- recommended function P-RNAV equipment
- requirement for future RNP 1 equipment

RNAV and NAPs

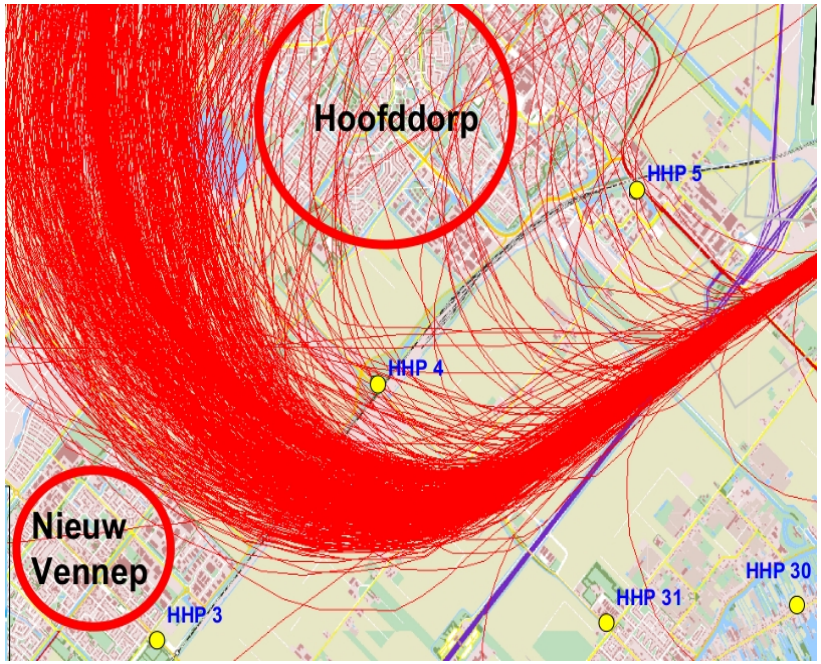


Conventional Navigation

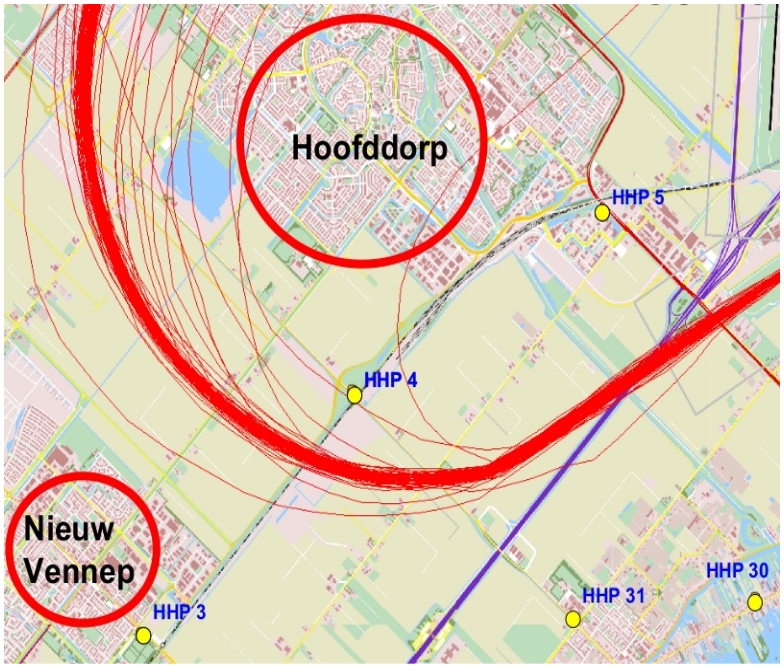


RNAV Navigation

RNAV and NAPs



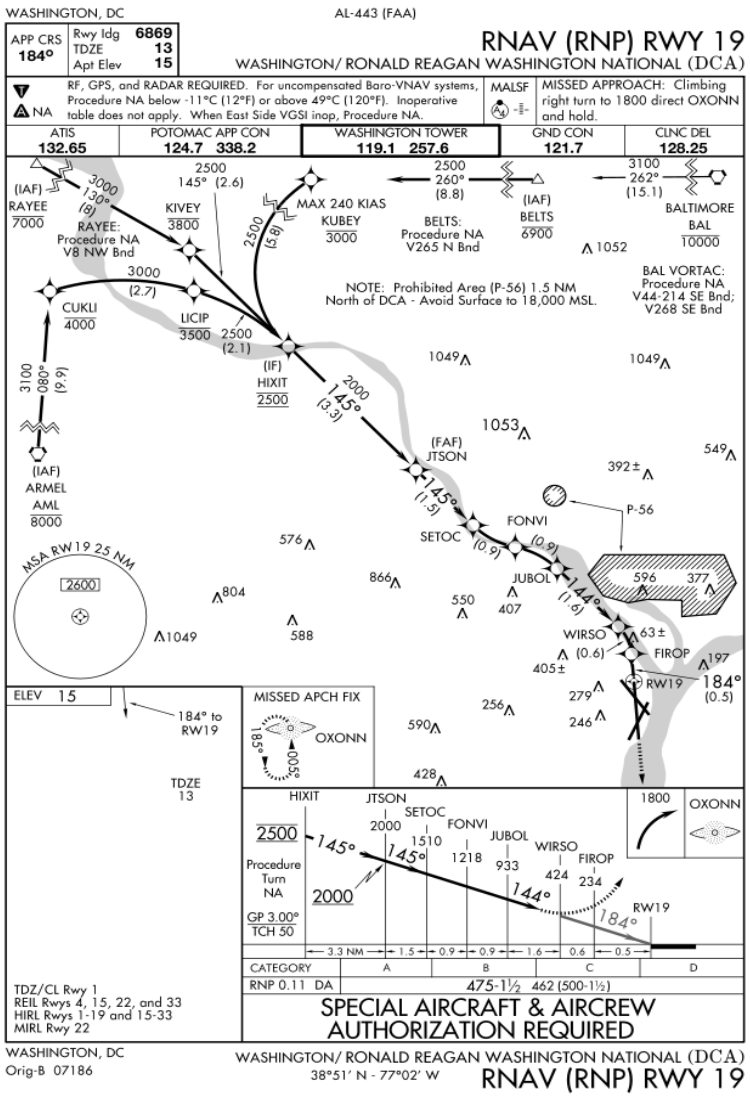
All aircraft

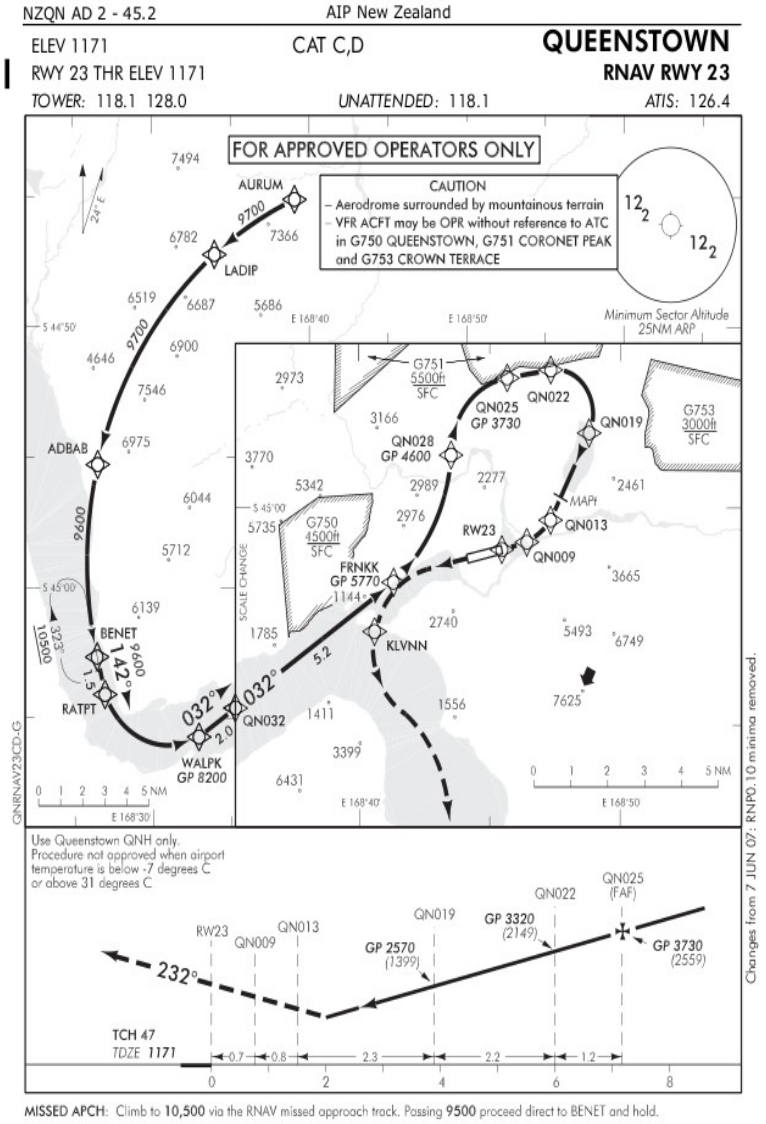


RNAV + RF equipped aircraft

Courtesy of Theo van de Ven (KLM)

RNAV and NAPs





Noise Abatement Procedures

- Lateral Trajectory Management
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- Vertical Trajectory Management
  - Arrival/approach strategies
  - Depart strategies

Arrival/Approach strategies

- Low Drag-Low Power (LDLP) approach
- Higher ILS interception altitude
- Higher ILS glide-slope angle
- Dual landing thresholds
- Continuous Descend Approach (CDA)
- Three Degree Descelerating Approach (TDDA)

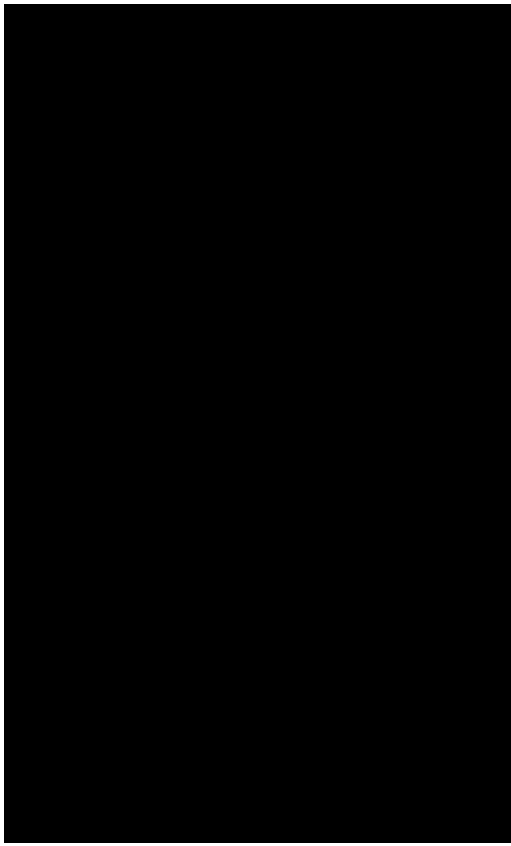
Compromise vs. airport and TMA CAPACITY

Depart strategies

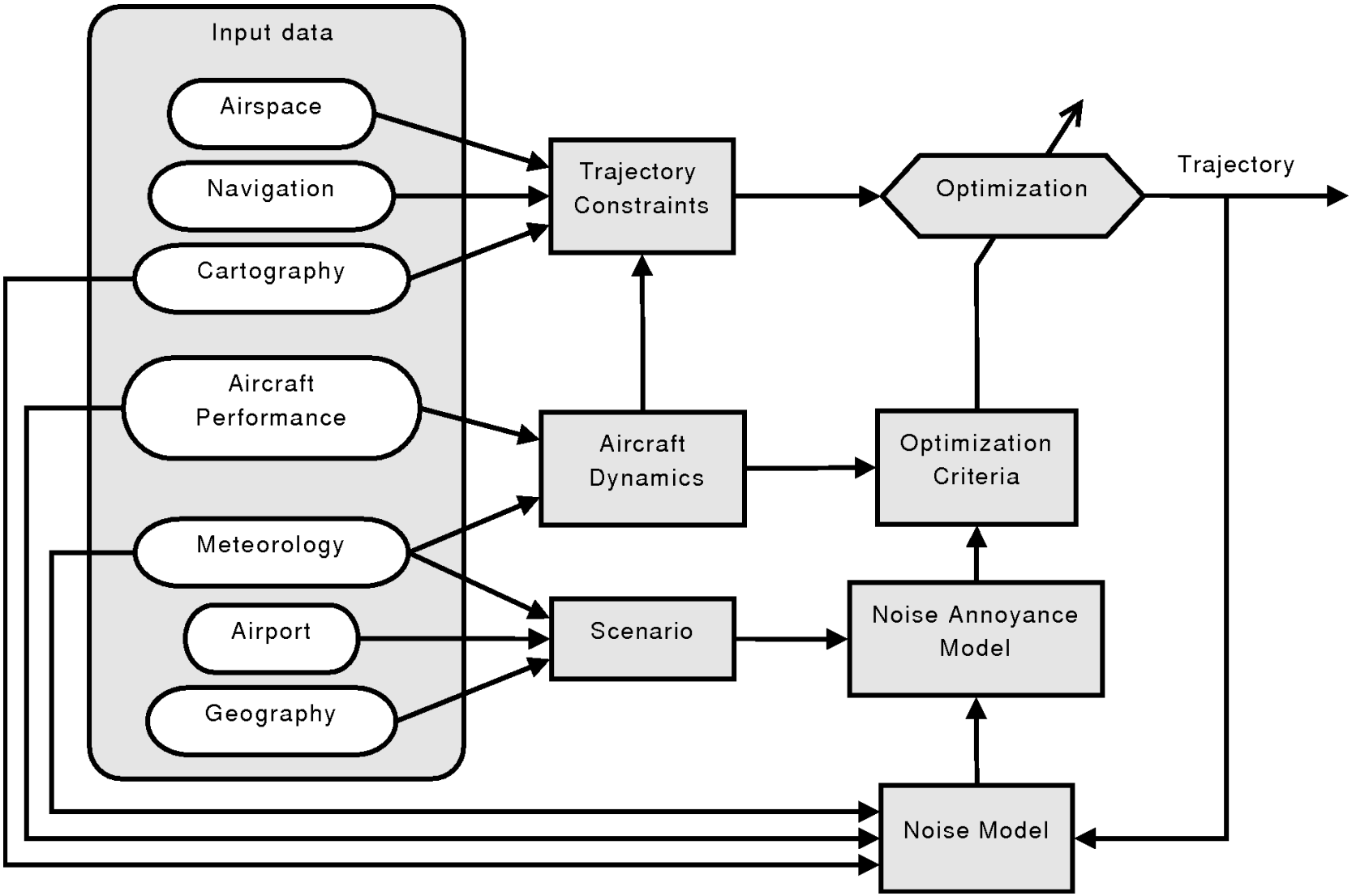
- Thrust cut-out
- Reduced thrust take-offs
- Different climbing (airspeed) profiles

Optimisation of NAPs?

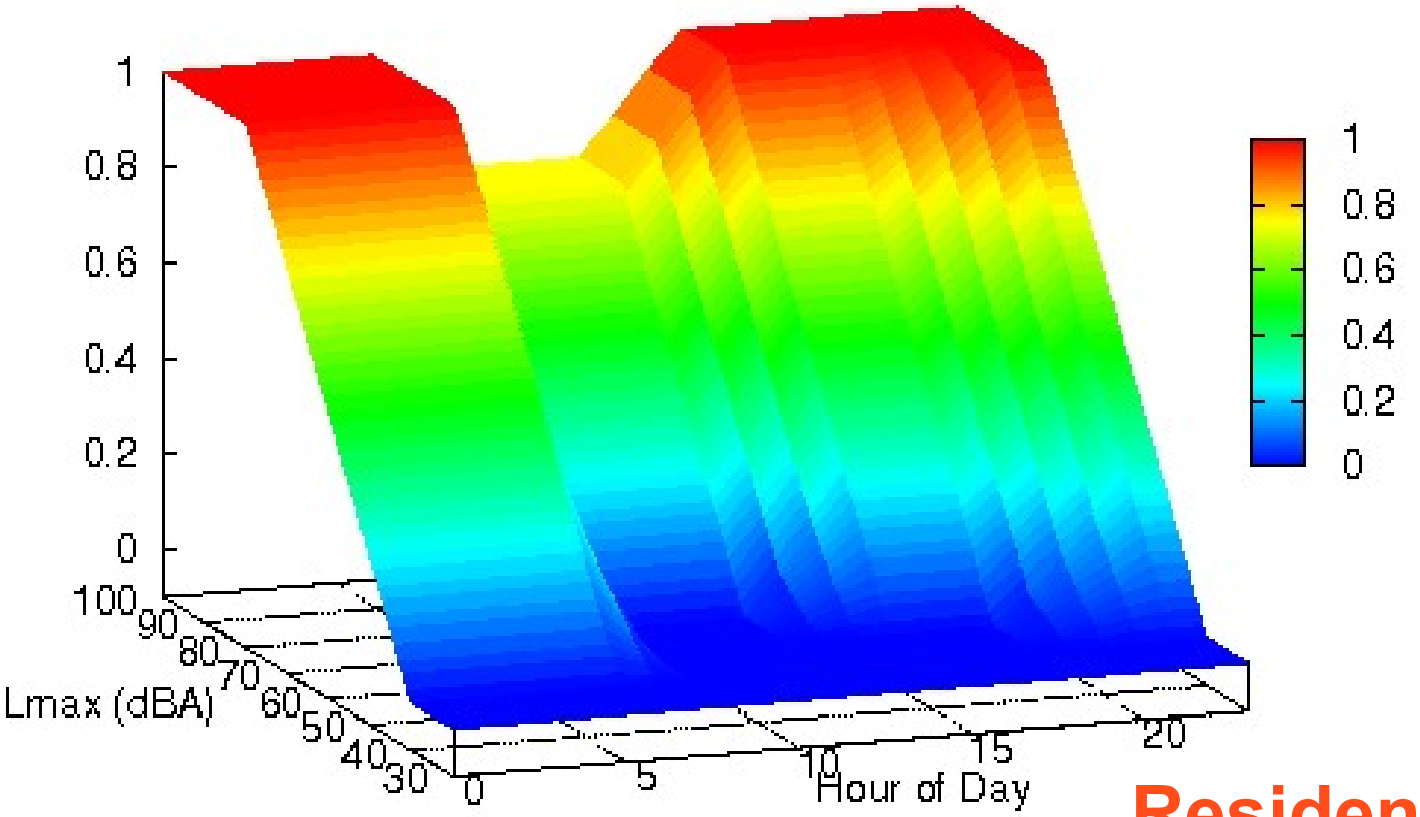
- Generic Procedures for specific problems
- Local sub-optimal solutions
- Noise annoyance partially assessed



NAPs optimisation framework

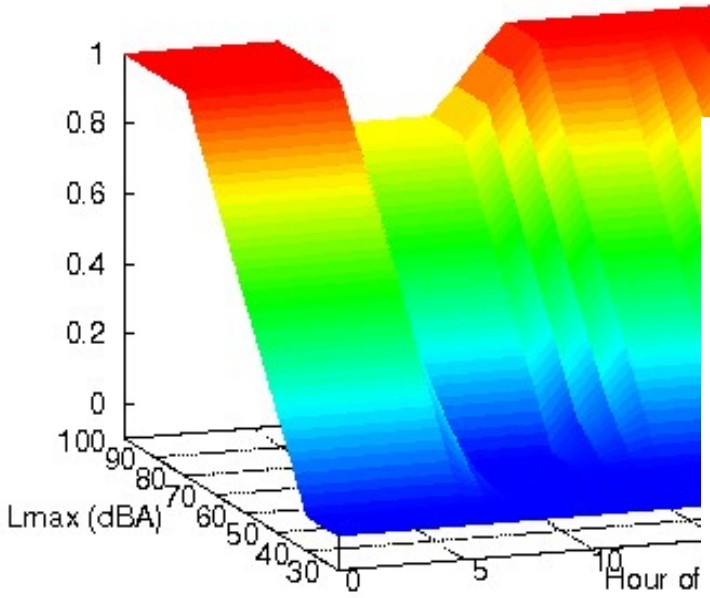


Fuzzy logic annoyance model



Residential Zone

Fuzzy logic annoyance model



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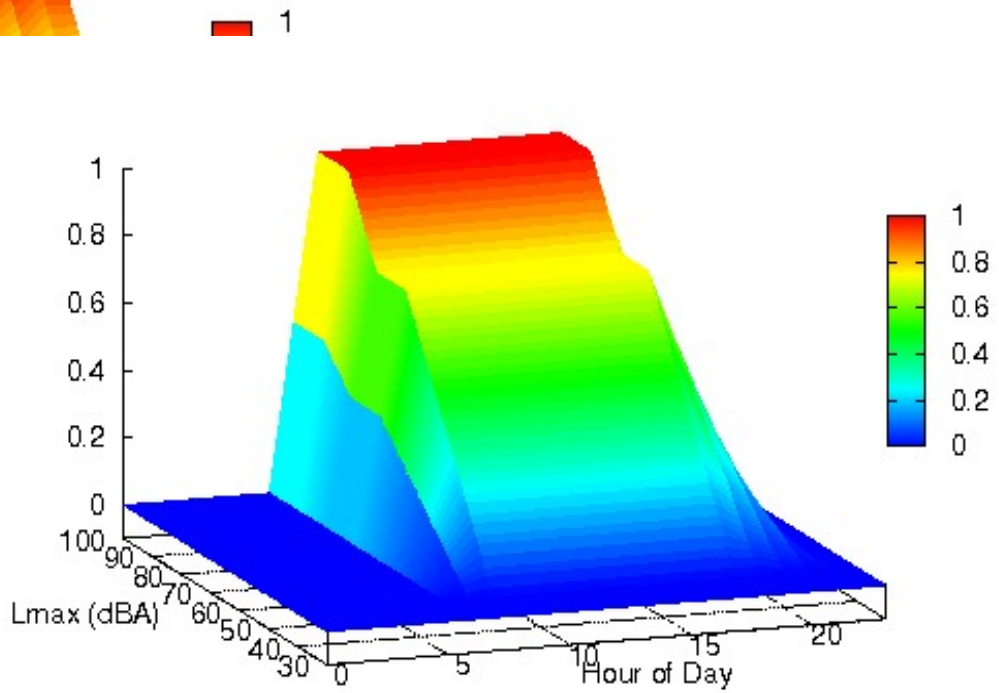
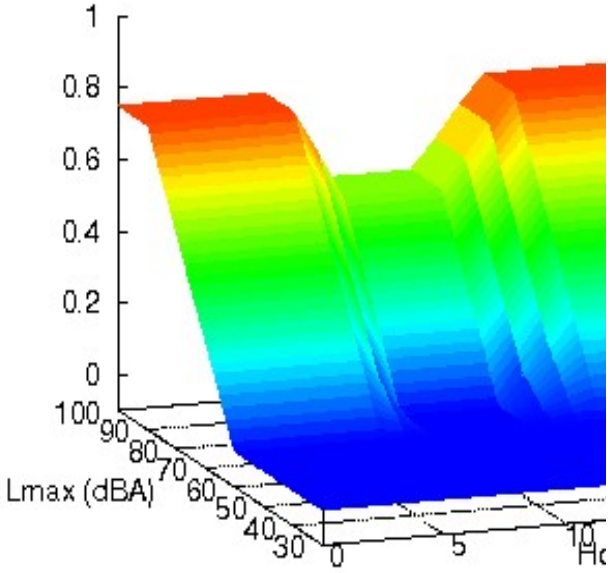
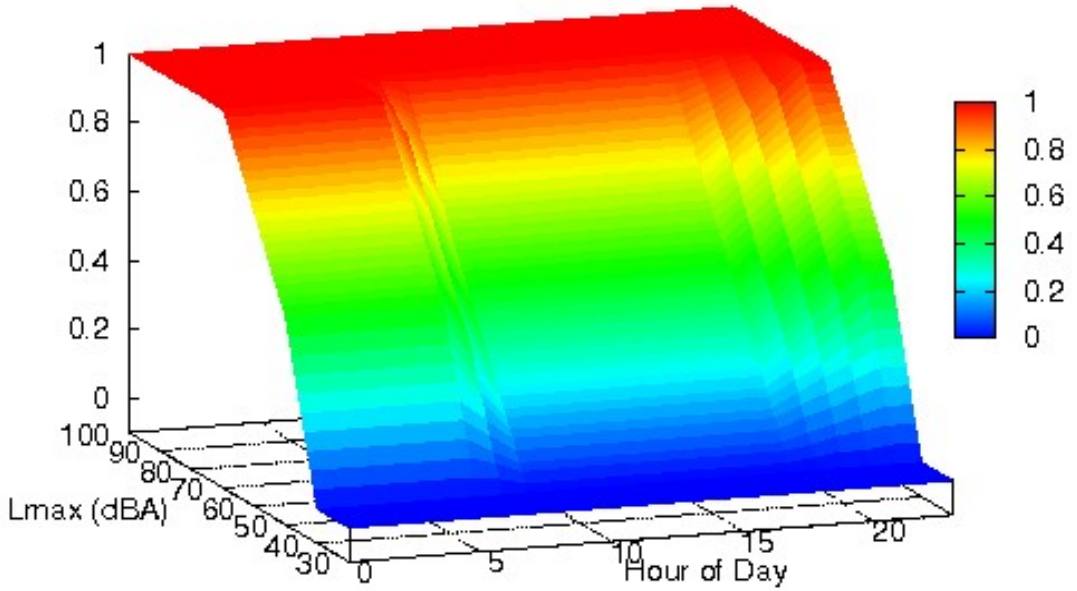


School

Fuzzy logic annoyance model



Industrial zone



Hospital

Trajectory optimisation

- Several noise annoyance values:
  - Hospital → A_H
  - Industrial Zone → A_I
  - Residential Zone → A_R
  - School → A

Minimize A_H, A_I, A_R, A_S ??

Multiobjective optimization

Multiobjective optimization

$$\min_{\vec{z}\in\mathcal{Z}} \left[J_1(\vec{z}), J_2(\vec{z}), \cdots, J_{n_j}(\vec{z})\right]$$

"Average" trajectory

$$\min_{\vec{z}\in\mathcal{Z}} \sum_{i=1}^{n_j} w_i J_i(\vec{z})$$

"Fair" trajectory

$$\min_{\vec{z}\in\mathcal{Z}} \left[\max_i(\Delta_i)\right]$$

$$\Delta_i = J_i - J_i^*$$

Multiobjective optimization

$$\min_{\vec{z}\in\mathcal{Z}} \left[J_1(\vec{z}), J_2(\vec{z}), \cdots, J_{n_j}(\vec{z})\right]$$

Egalitarian principle:

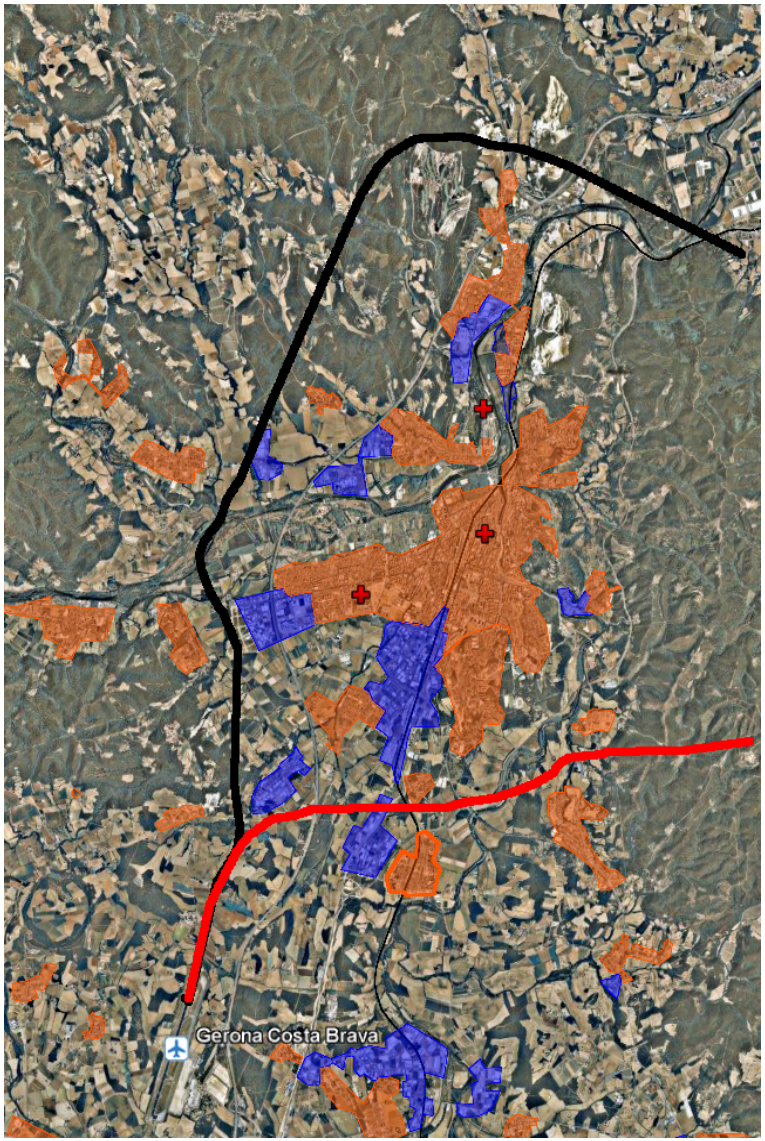
the system is no better-off than its worse-off individual

"Fair" trajectory

$$\min_{\vec{z}\in\mathcal{Z}} \left[\max_i(\Delta_i)\right]$$

$$\Delta_i = J_i - J_i^*$$

Application example



Girona (LEGE) international airport

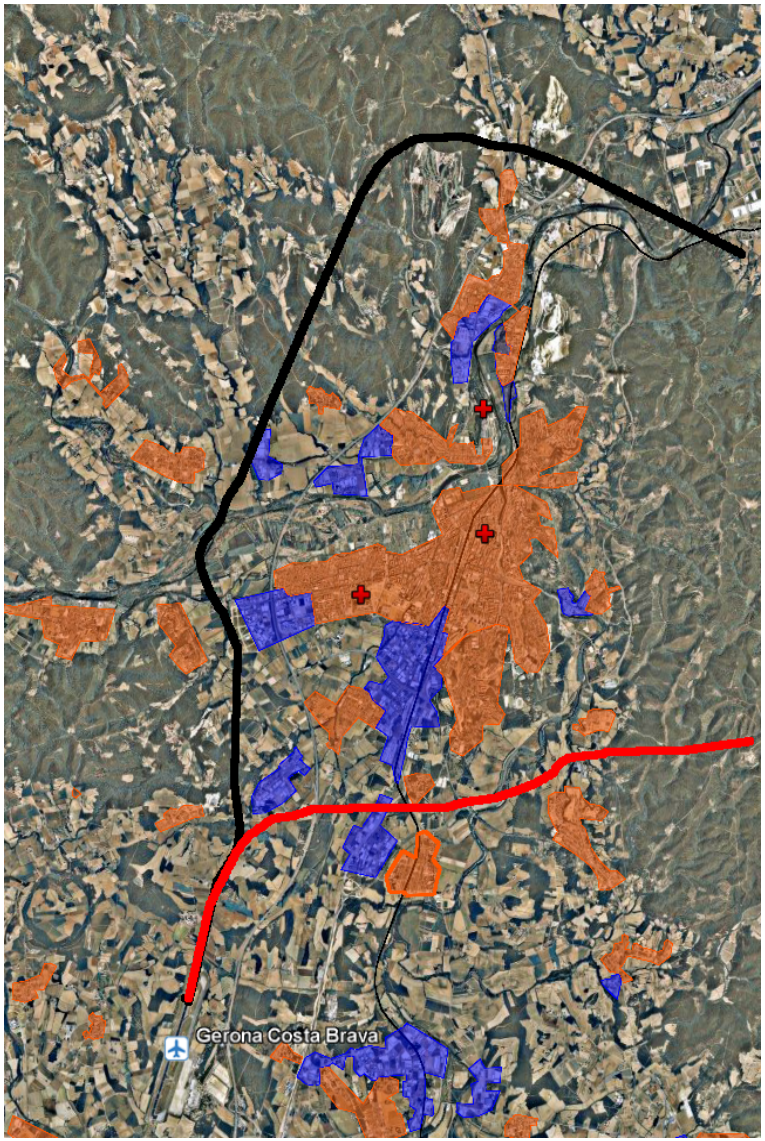
Airbus A340-600 departure

Hospitals (Annoyance < 0.25)

Residential

Industrial zones

Application example



Girona (LEGE) international airport

Airbus A340-600 departure

04 am

10 am

Conclusions

- RNAV and RNP are major enablers for efficient Noise Abatement Procedures
- Trajectory multi-objective optimisation problem to be solved
- Noise annoyance can be taken into account by using a fuzzy logic model
- Egalitarian principle for noise abatement multi criteria optimisation

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Thank you!

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