Autum School 2025

Introduction to Air Traffic Management and mobility modelling

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27 Oct 2025

Transportation Research Laboratory

Quintin Hogg Trust

Flying

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VFR – Visual Flight Rules

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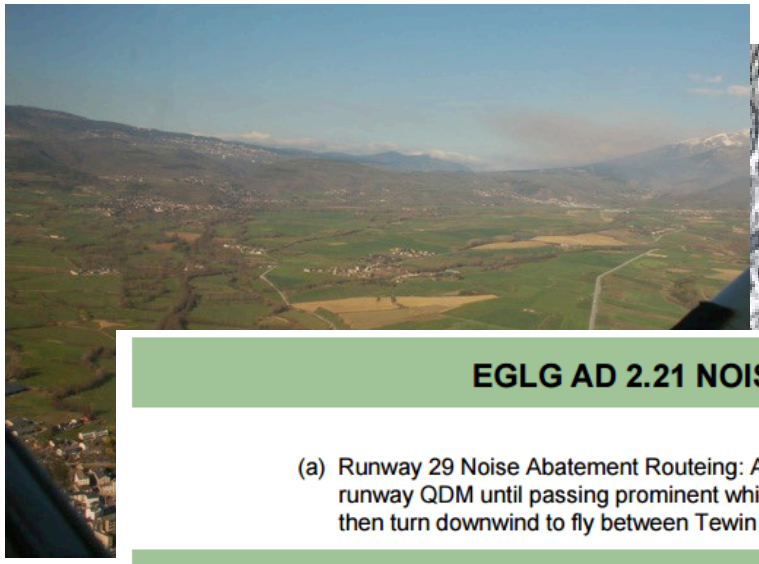
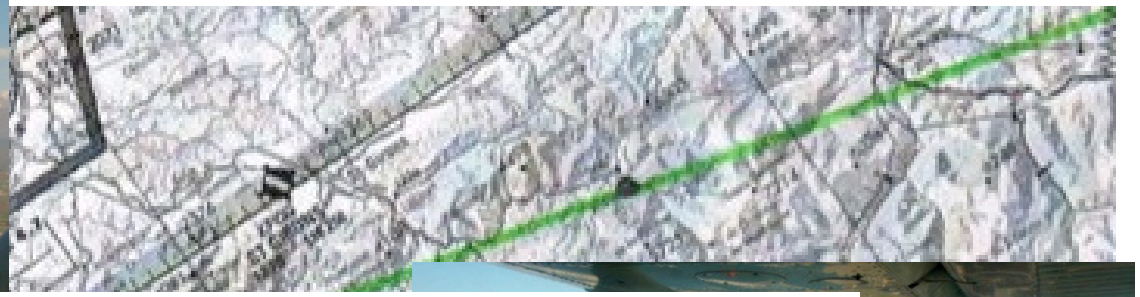
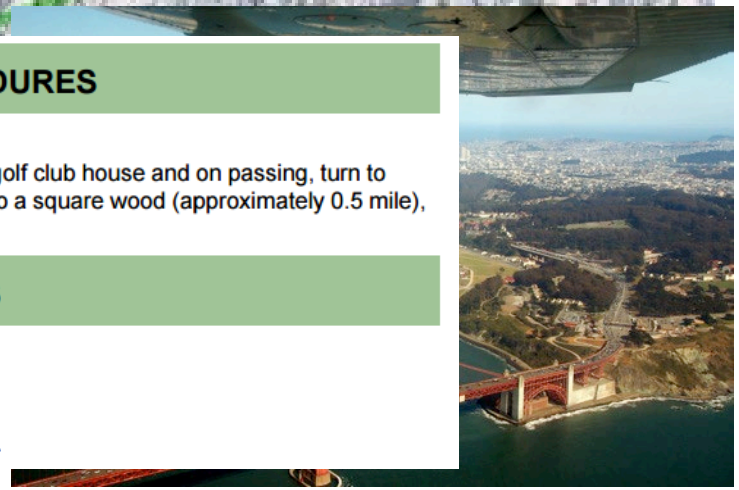
Clean Sky

- **VFR: Visual Flight Rules**
  - Visual ground landmarks or references
  - Radionavigation as optional/support means







EGLG AD 2.21 NOISE ABATEMENT PROCEDURES

(a) Runway 29 Noise Abatement Routeing: After take-off, turn right to overfly the golf club house and on passing, turn to runway QDM until passing prominent white building (School). Turn right to fly to a square wood (approximately 0.5 mile), then turn downwind to fly between Tewin and Tewin Wood.

EGLG AD 2.22 FLIGHT PROCEDURES

1 Circuits

(a) Circuit directions: Runway 29 - RH; Runway 11 - LH. Circuit height: 1000 ft aal.

VFR – Departures and approaches

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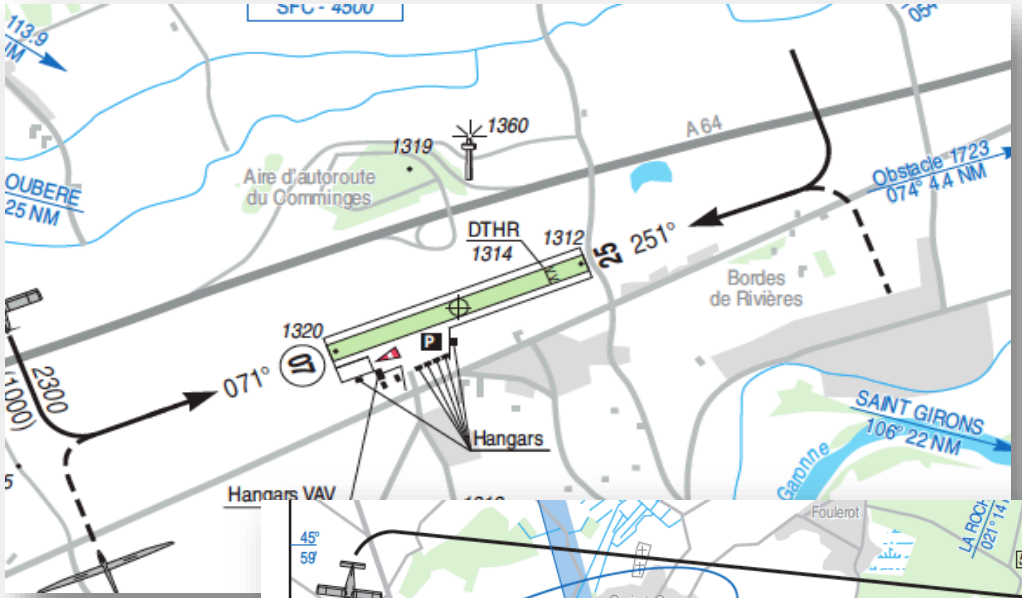
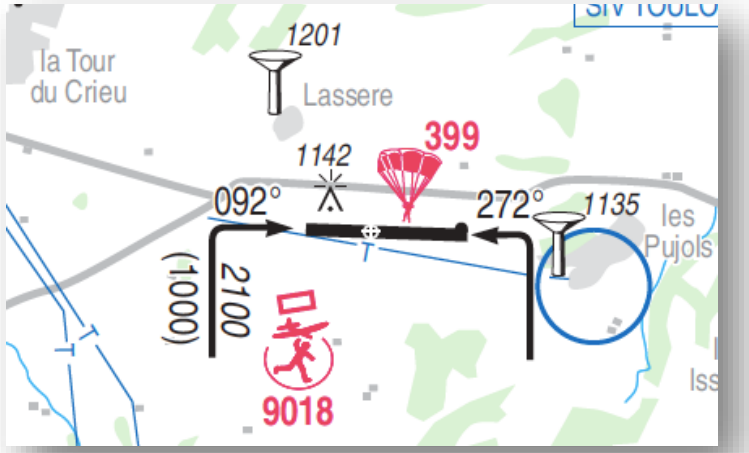
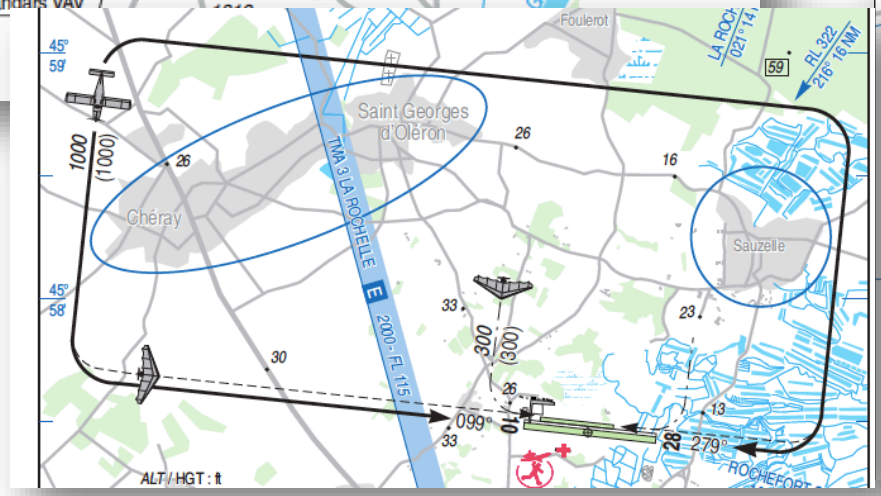
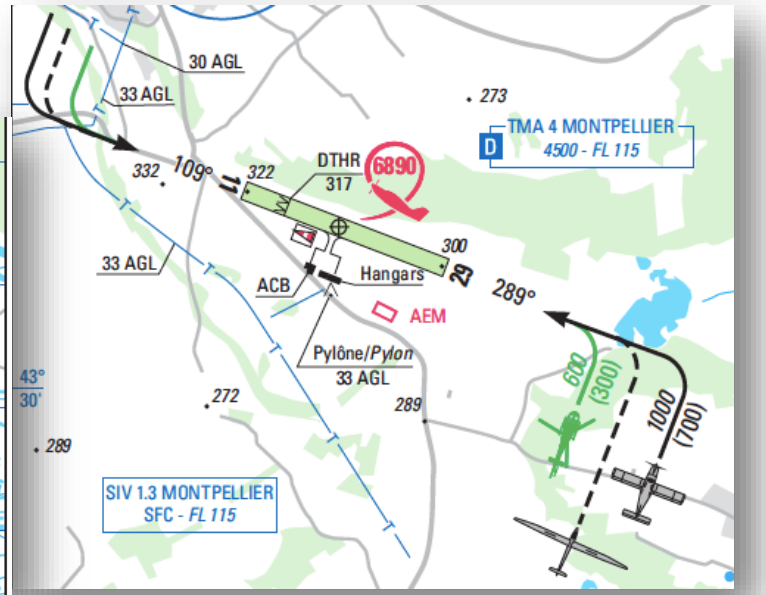
Airfield traffic pattern









VFR – Departures and approaches

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Clean Sky

Airfield traffic pattern

VFR – Departures and approaches

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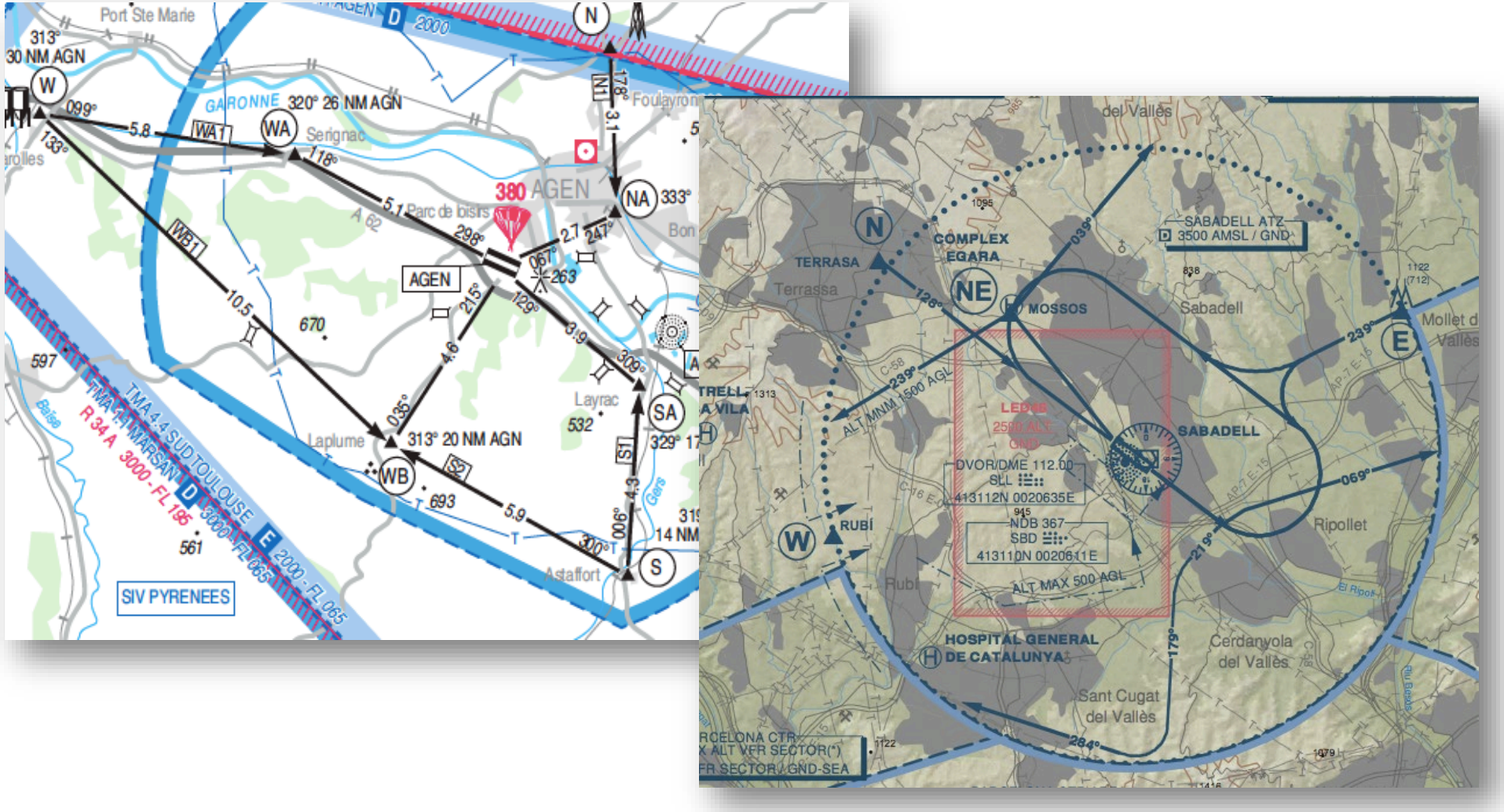
VFR reporting points



IMC – Instrument Meteorological Conditions

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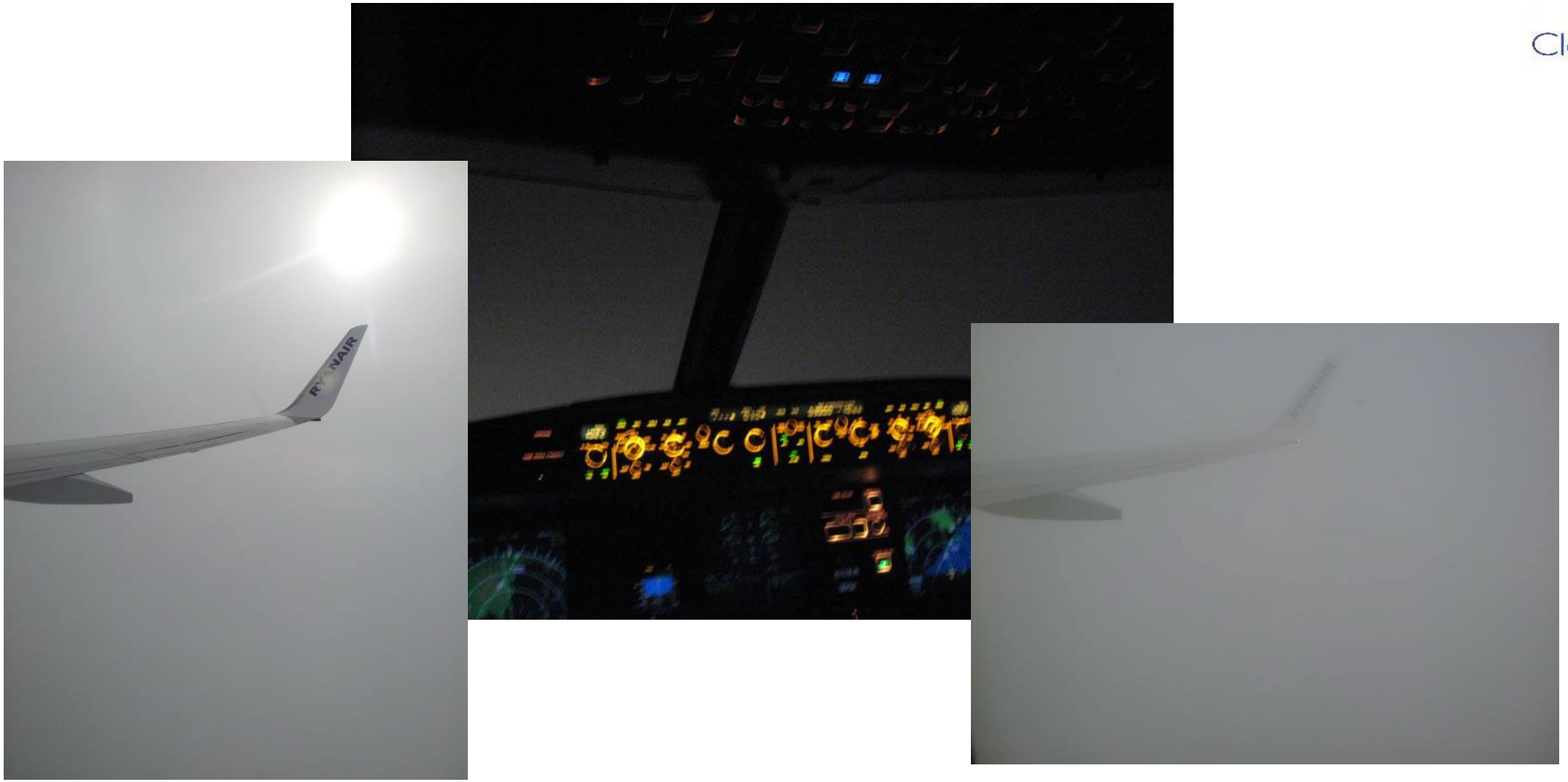

IFR – Instrumental Flight Rules

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Instrument flight procedures

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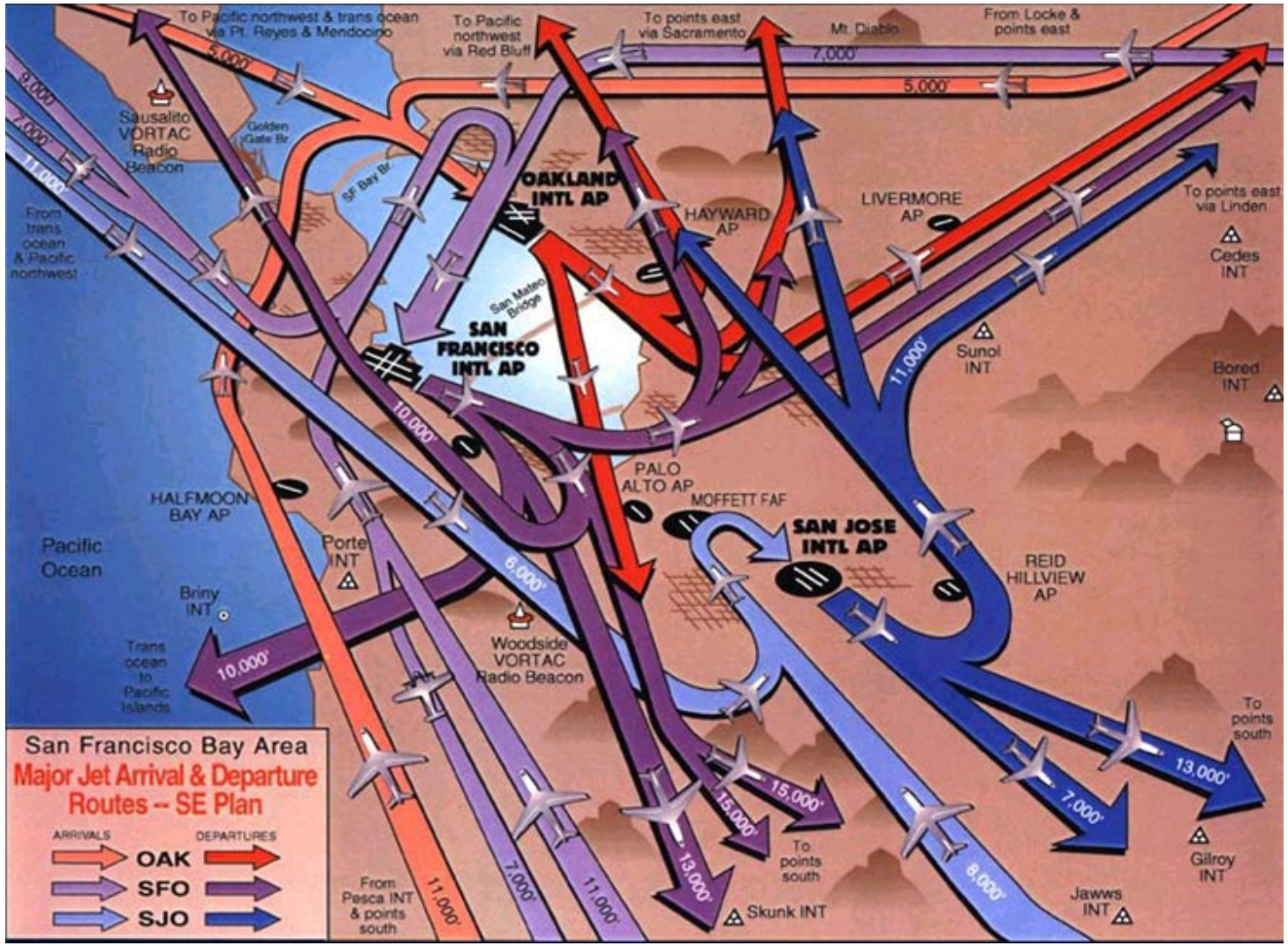
Clean Sky

Bay Terminal Radar Approach Control (TRACON) Traffic Flow



Flight phases and procedures

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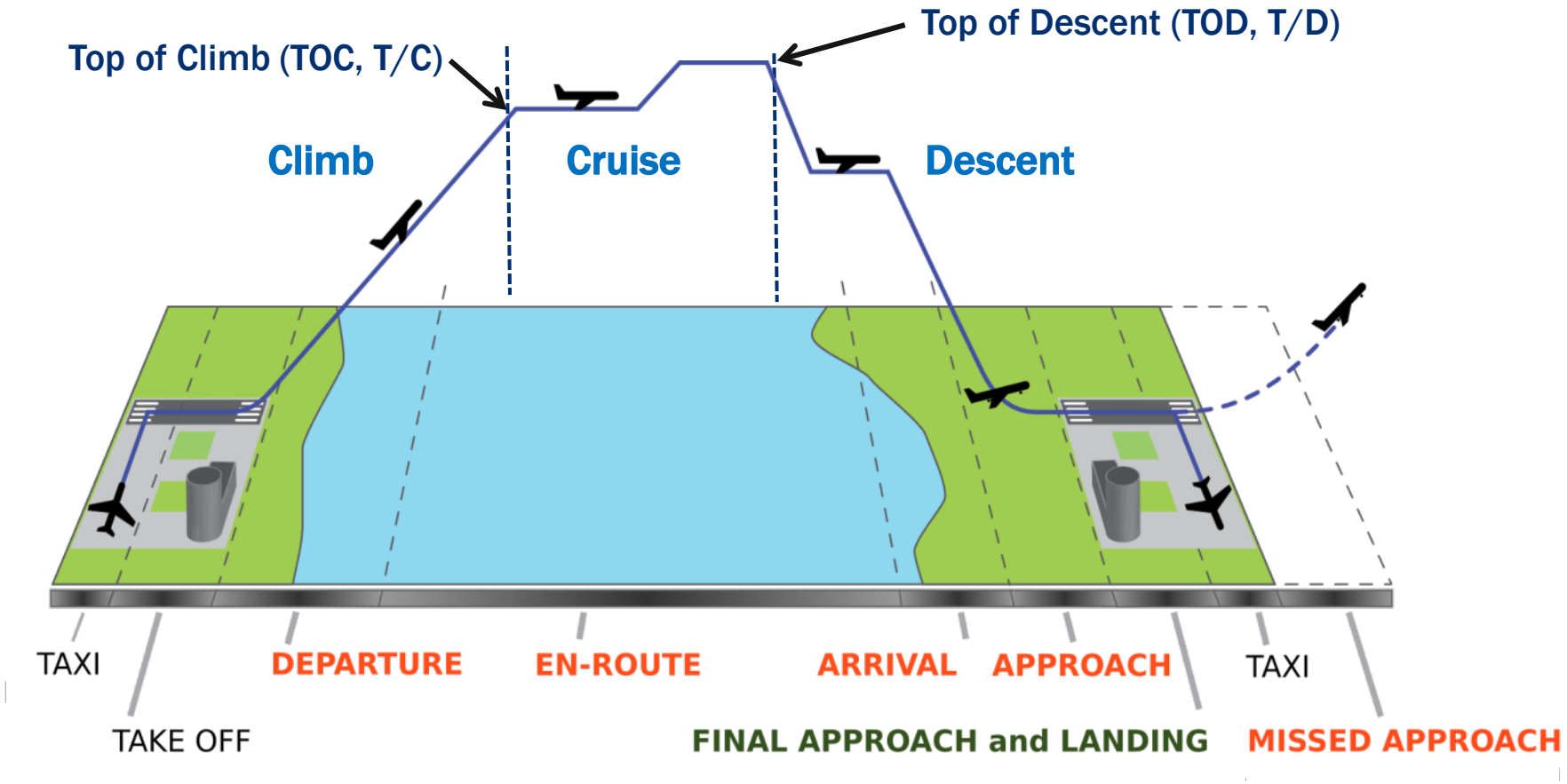

Departure procedures

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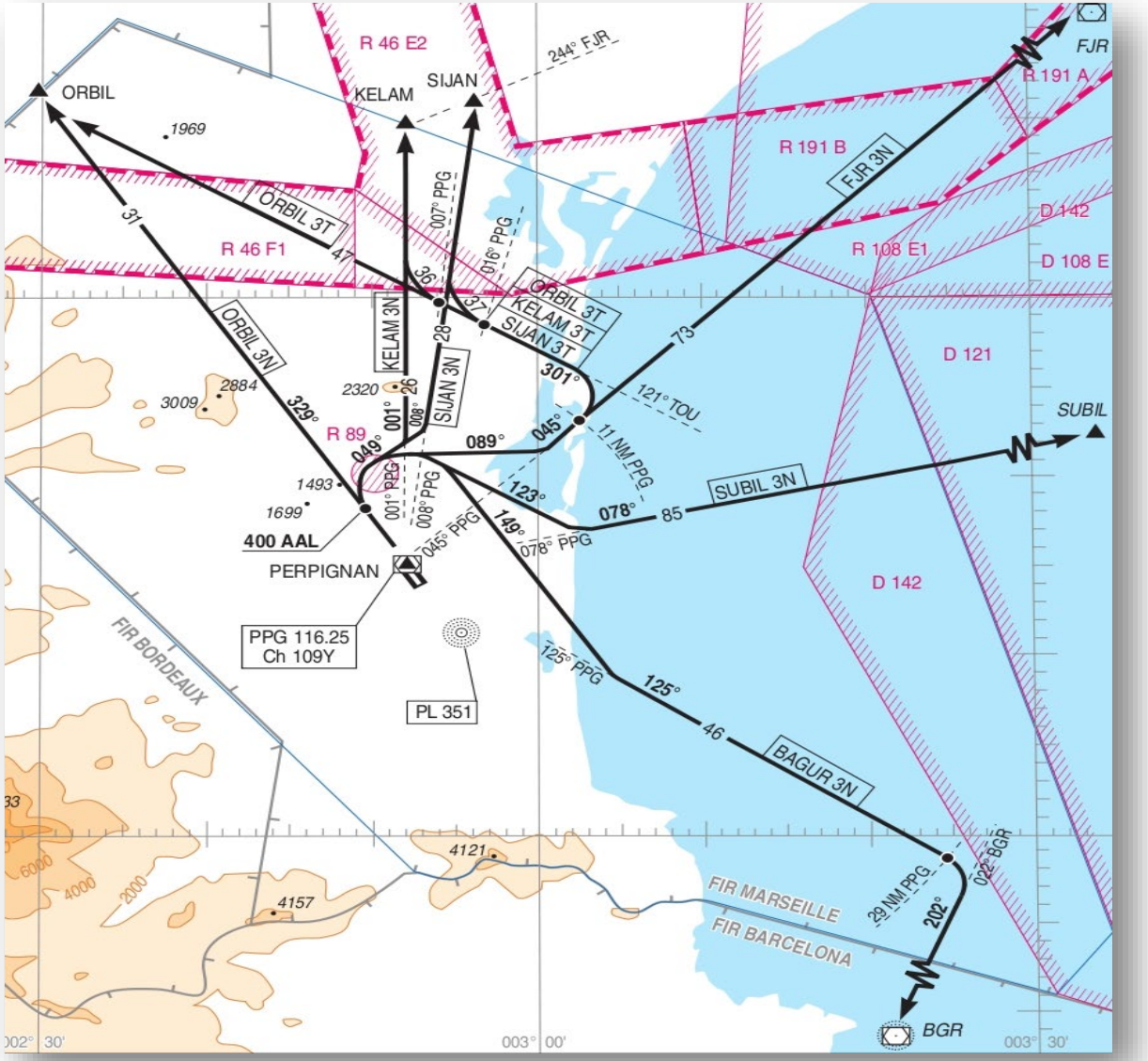
Standard Instrumental Departures (SID)



Departure procedures

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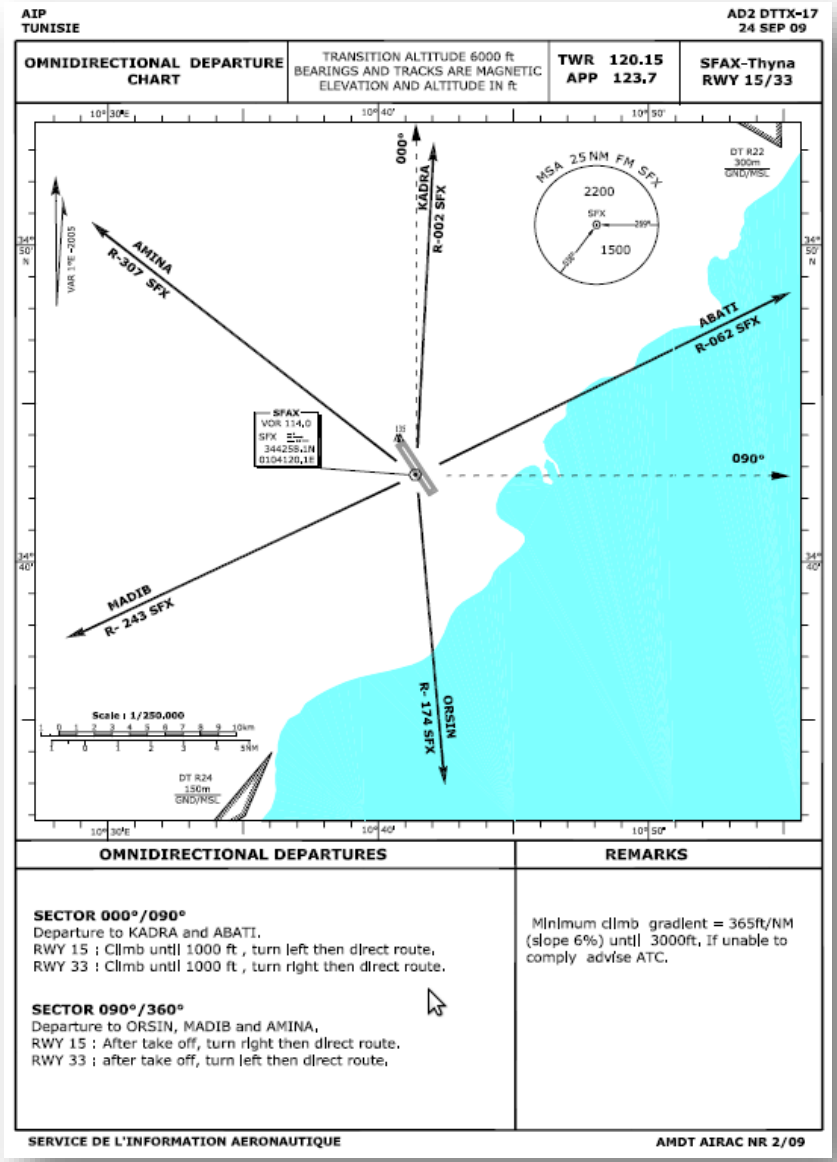
Omnidirectional Departures



En-route procedures

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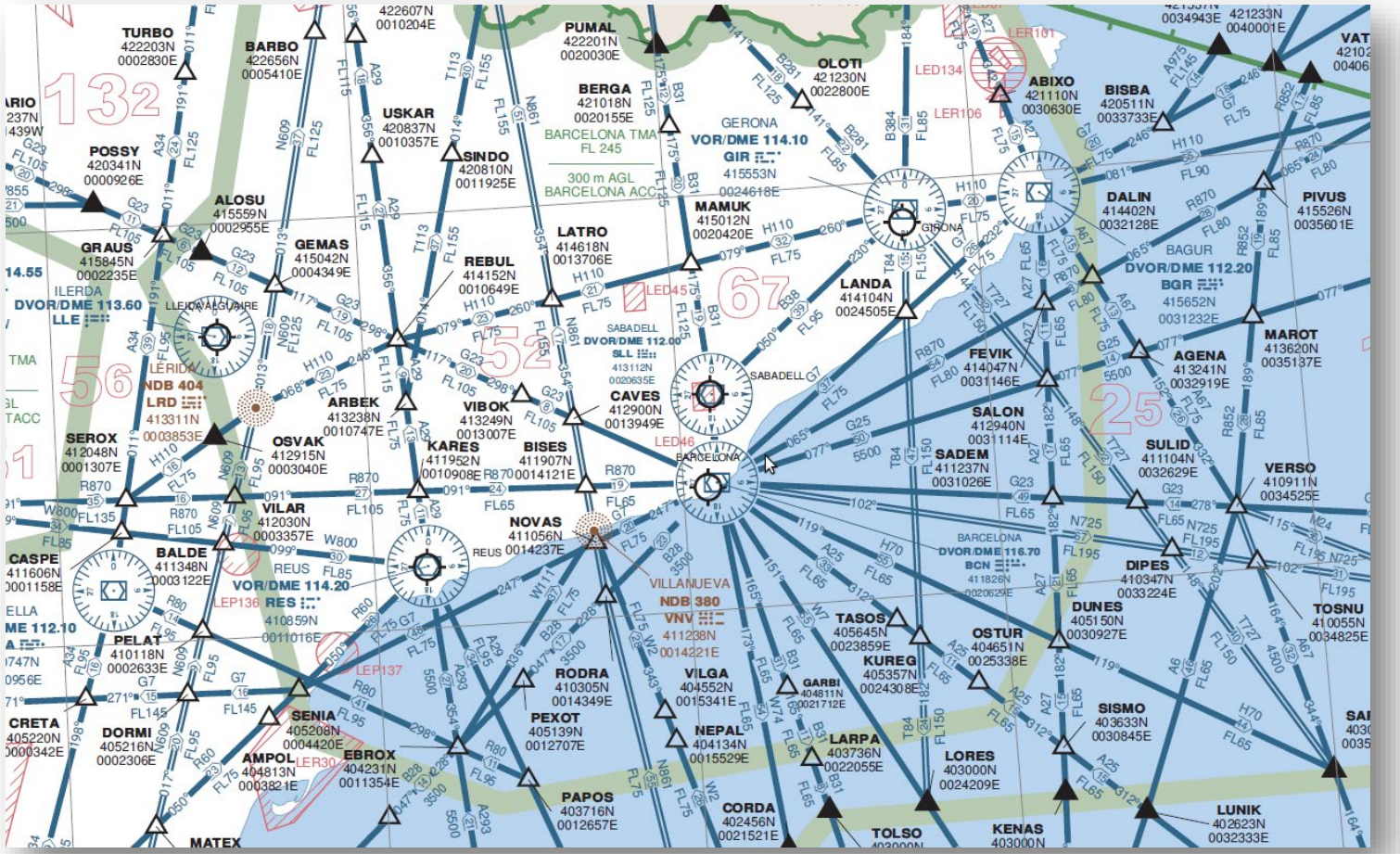
Airways



Arrival procedures

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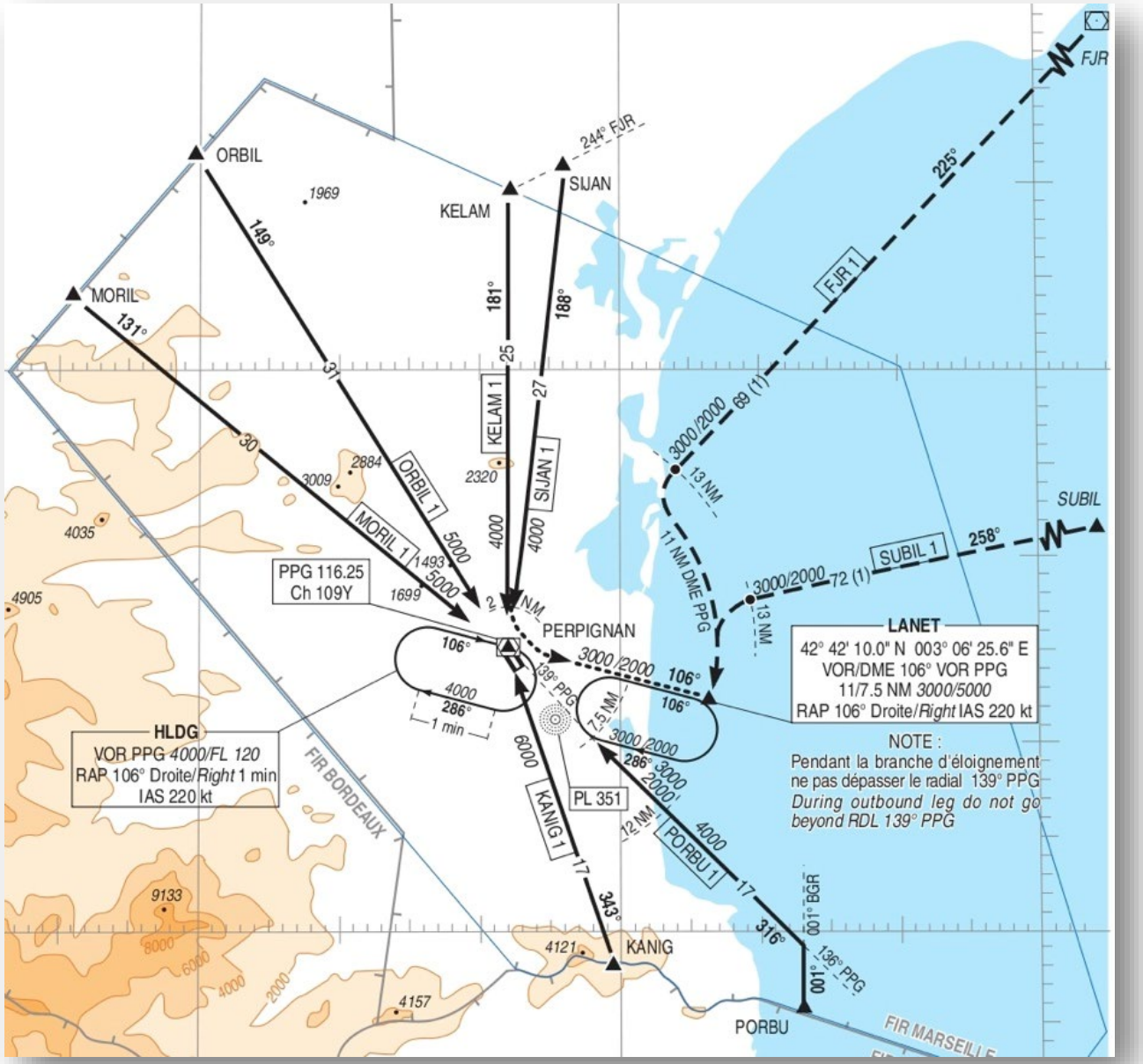
Clean Sky

Standard Terminal Arrival Routes (STAR)



Arrival procedures

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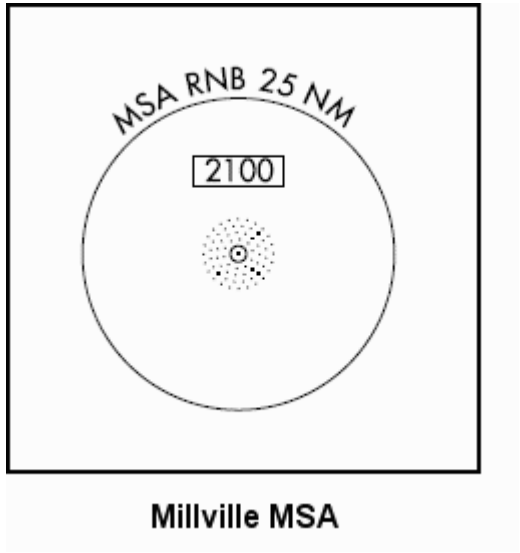
Omnidirectional Arrivals



Millville MSA

Approach procedures

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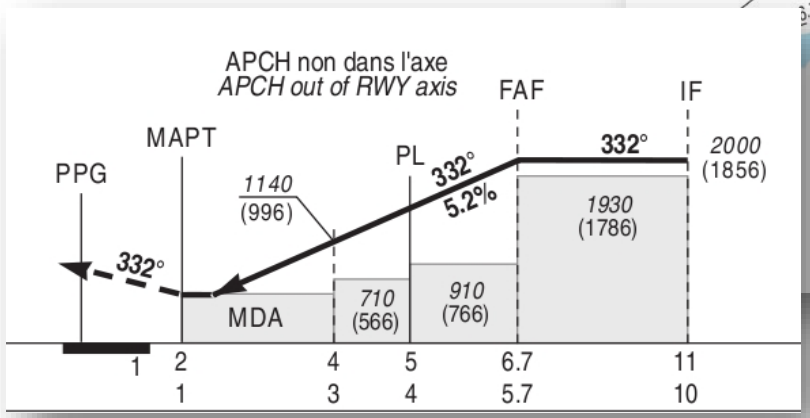

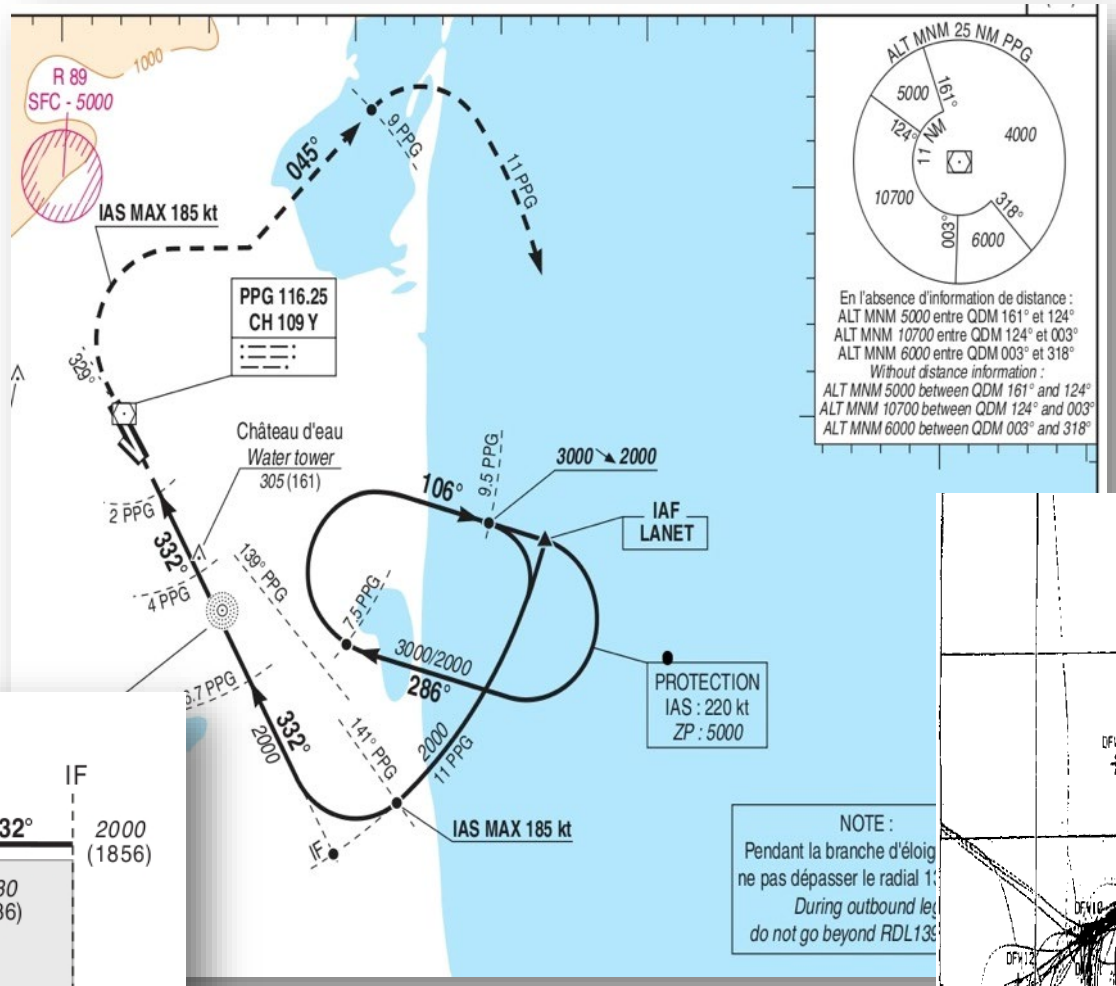

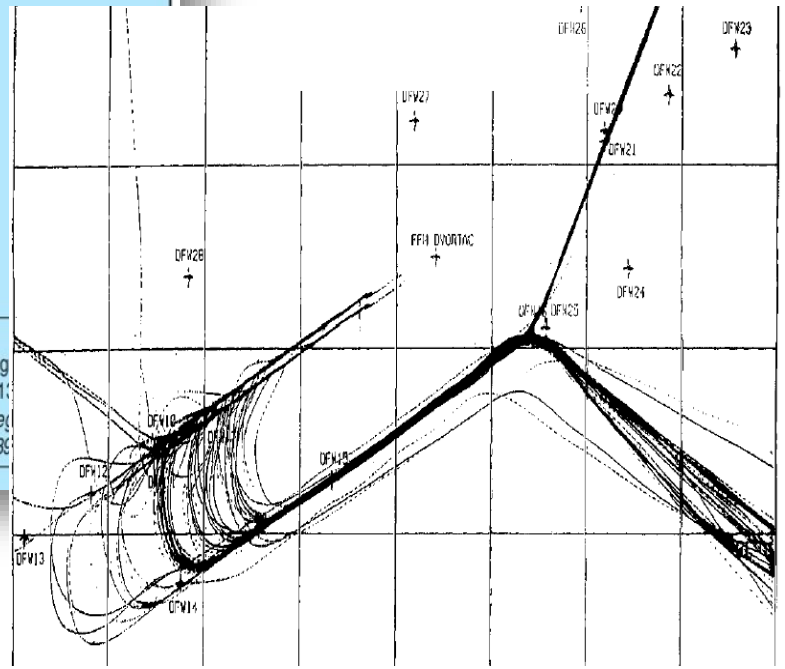

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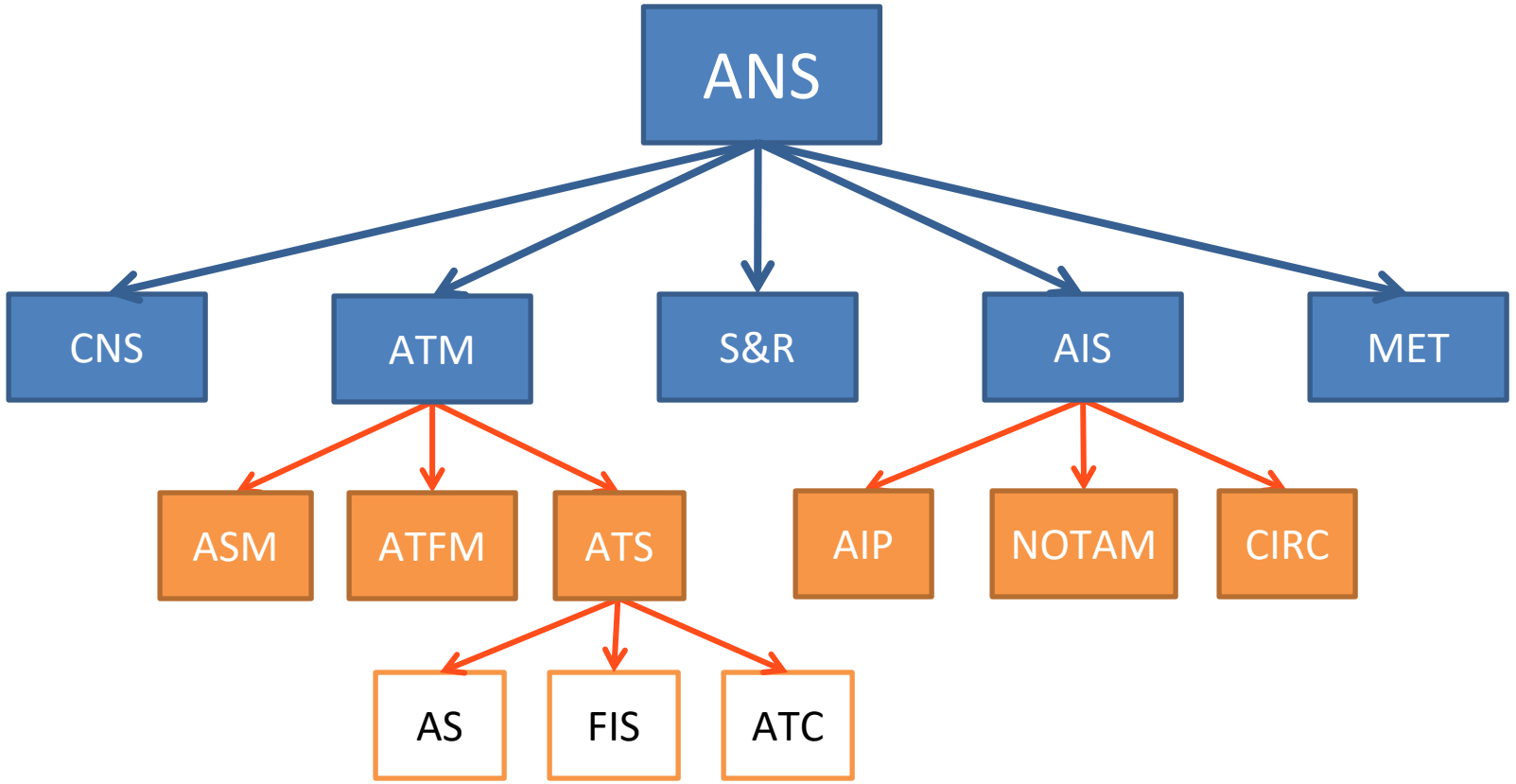
Air Traffic Management (ATM)

Air Navigation Services

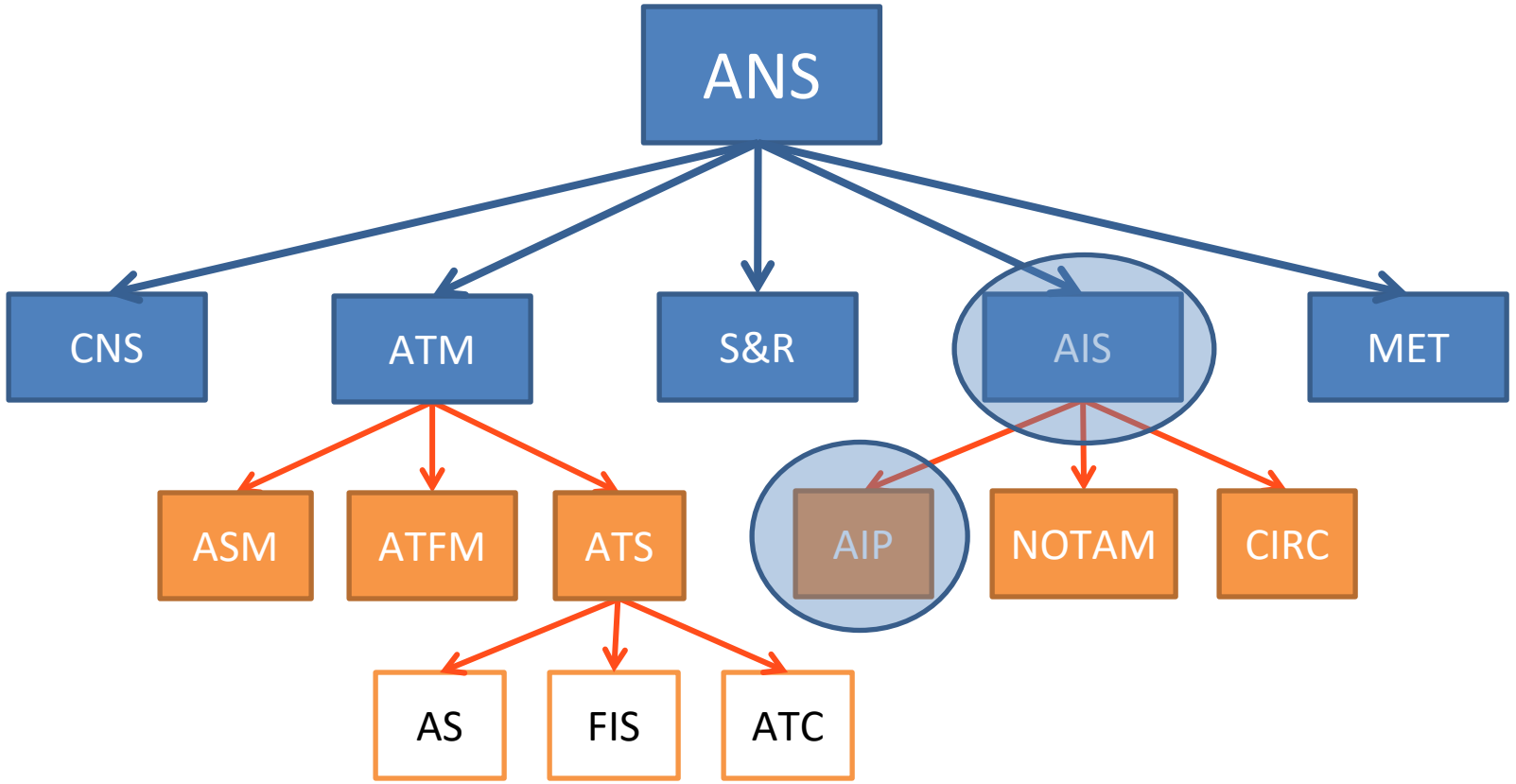


ANS: Air Navigation Services
CNS: Communications, Navigation and Surveillance
ATM: Air Traffic Management
S&R: Search and Rescue
AIS: Air Information Services
MET: Meteorological Services

ASM: AirSpace Management
ATFM: Air Traffic Flow Management
ATS: Air Traffic Services
AIP: Aeronautical Information Publications
NOTAM: Notices to Airmen
CIRC: Circulars

AS: Alert Services
FIS: Flight Information Services
ATC: Air Traffic Control

Air Information Services



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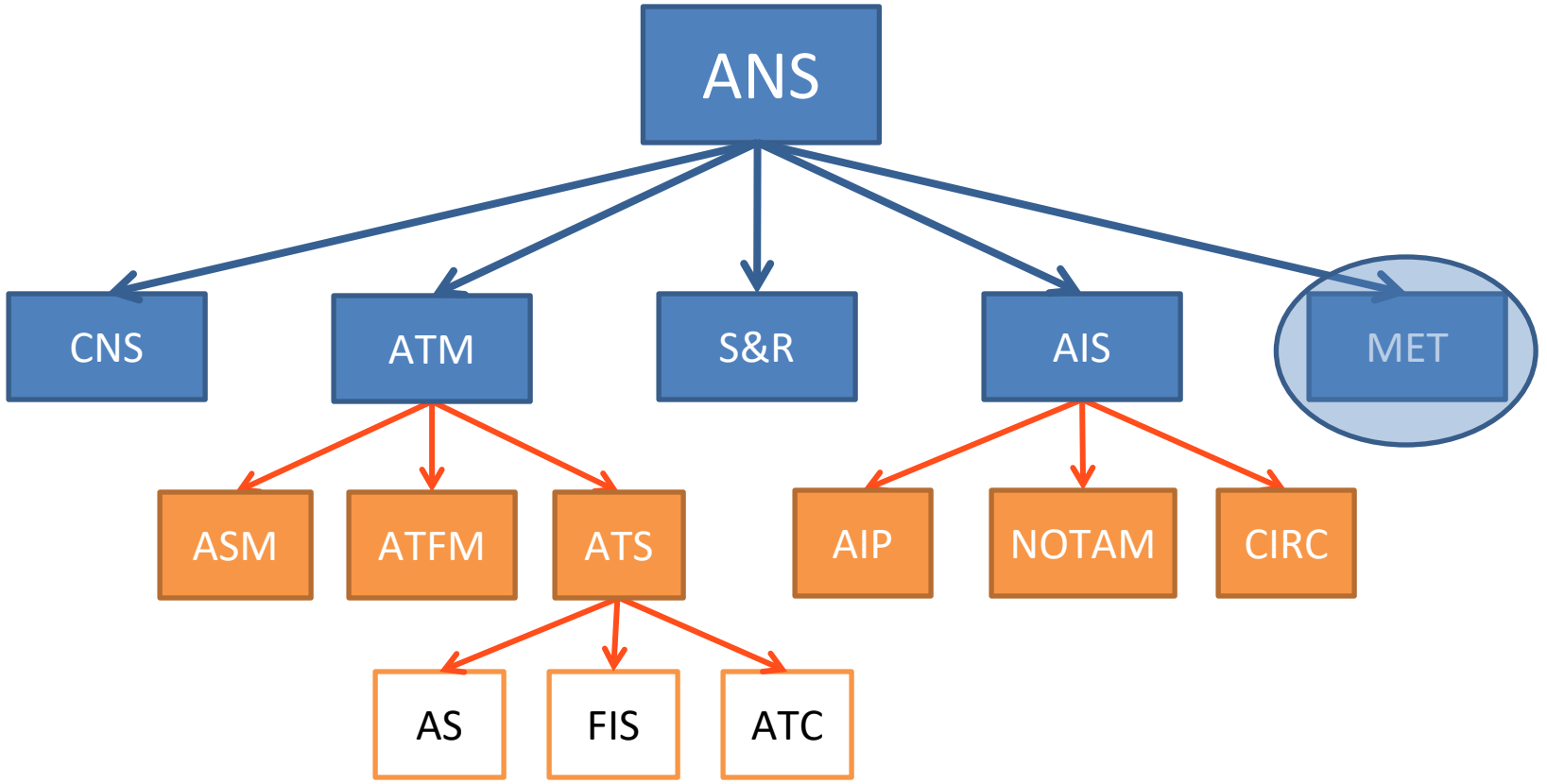
Meteorology



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Airspace Management

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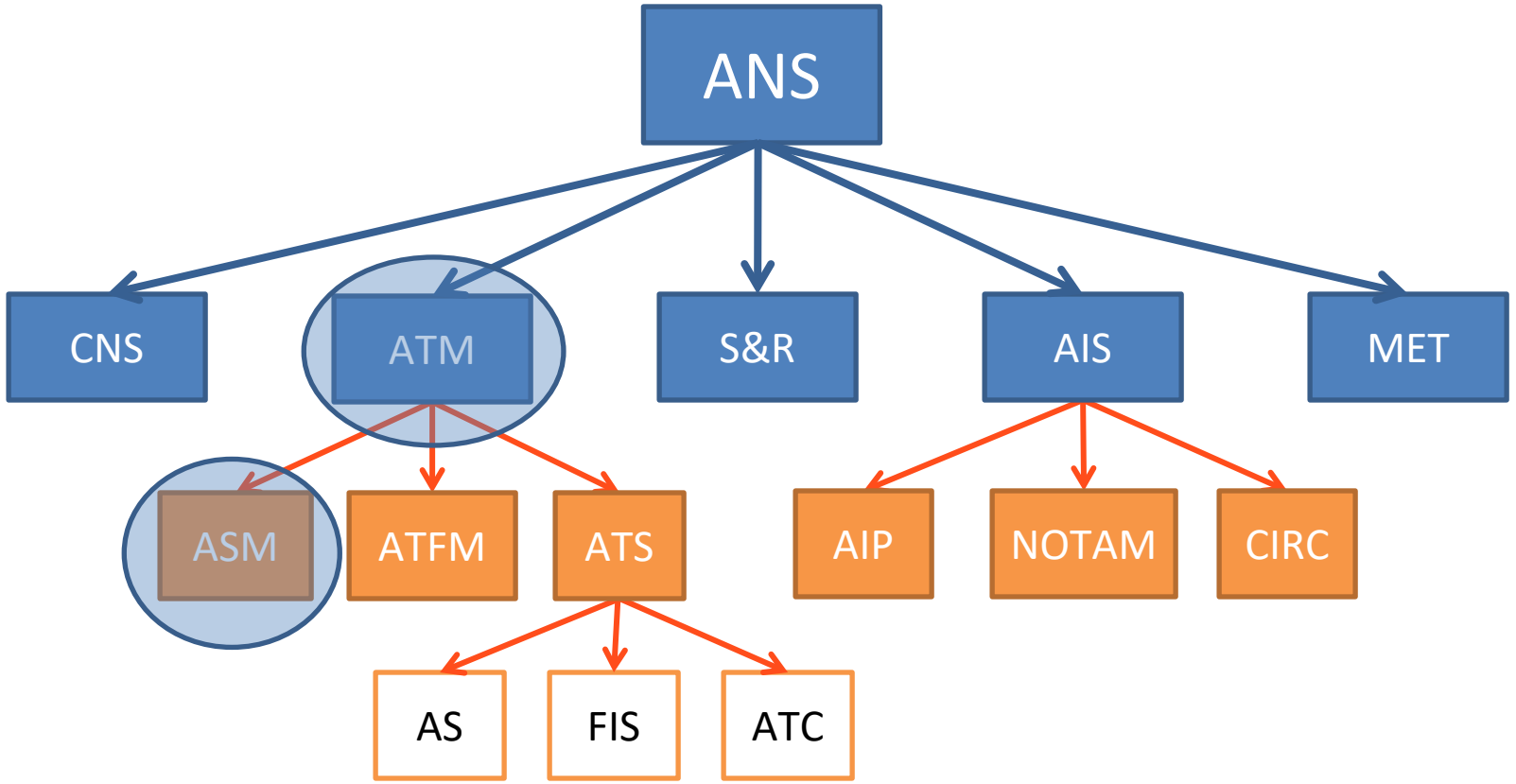

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Airspace Management

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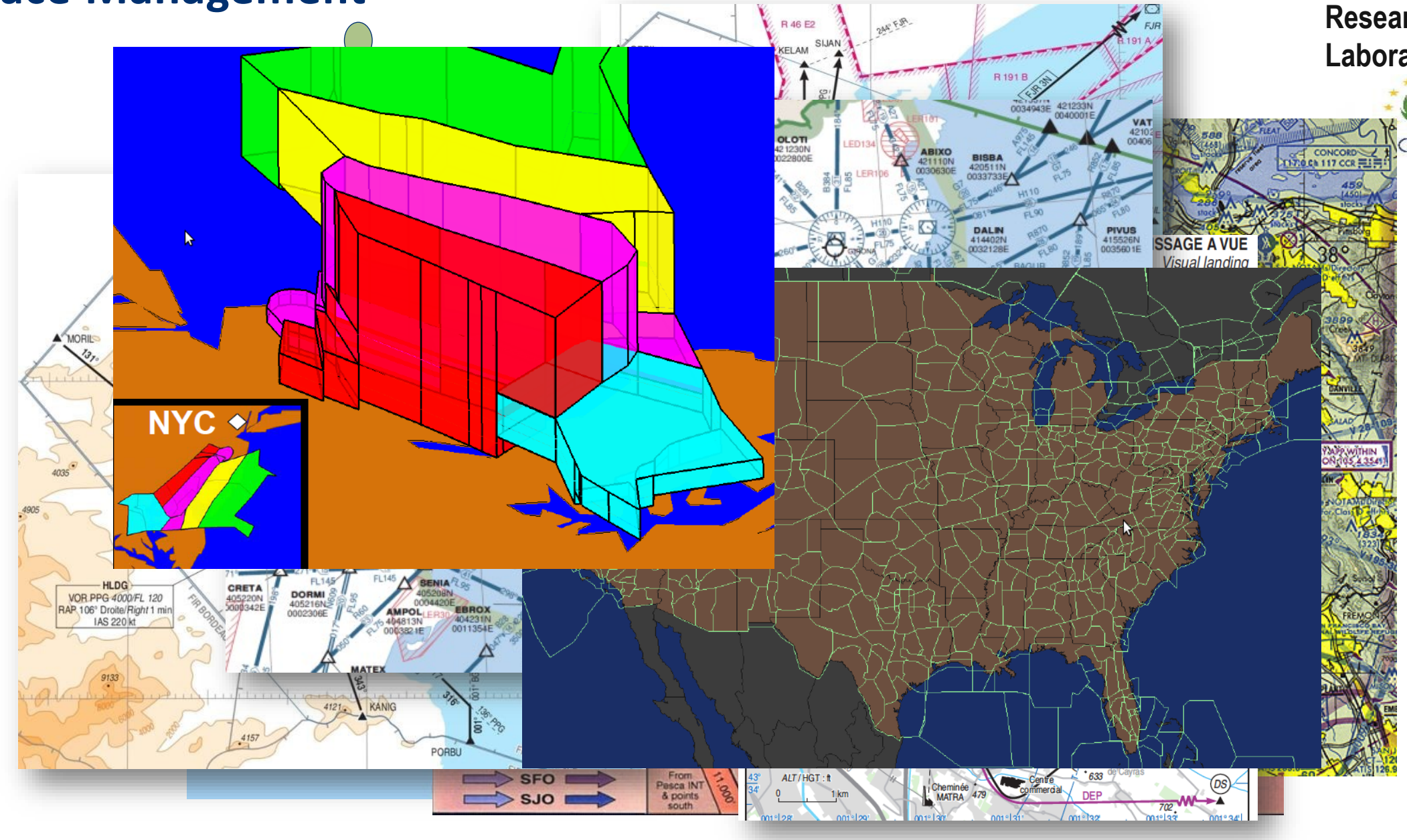

ATS units

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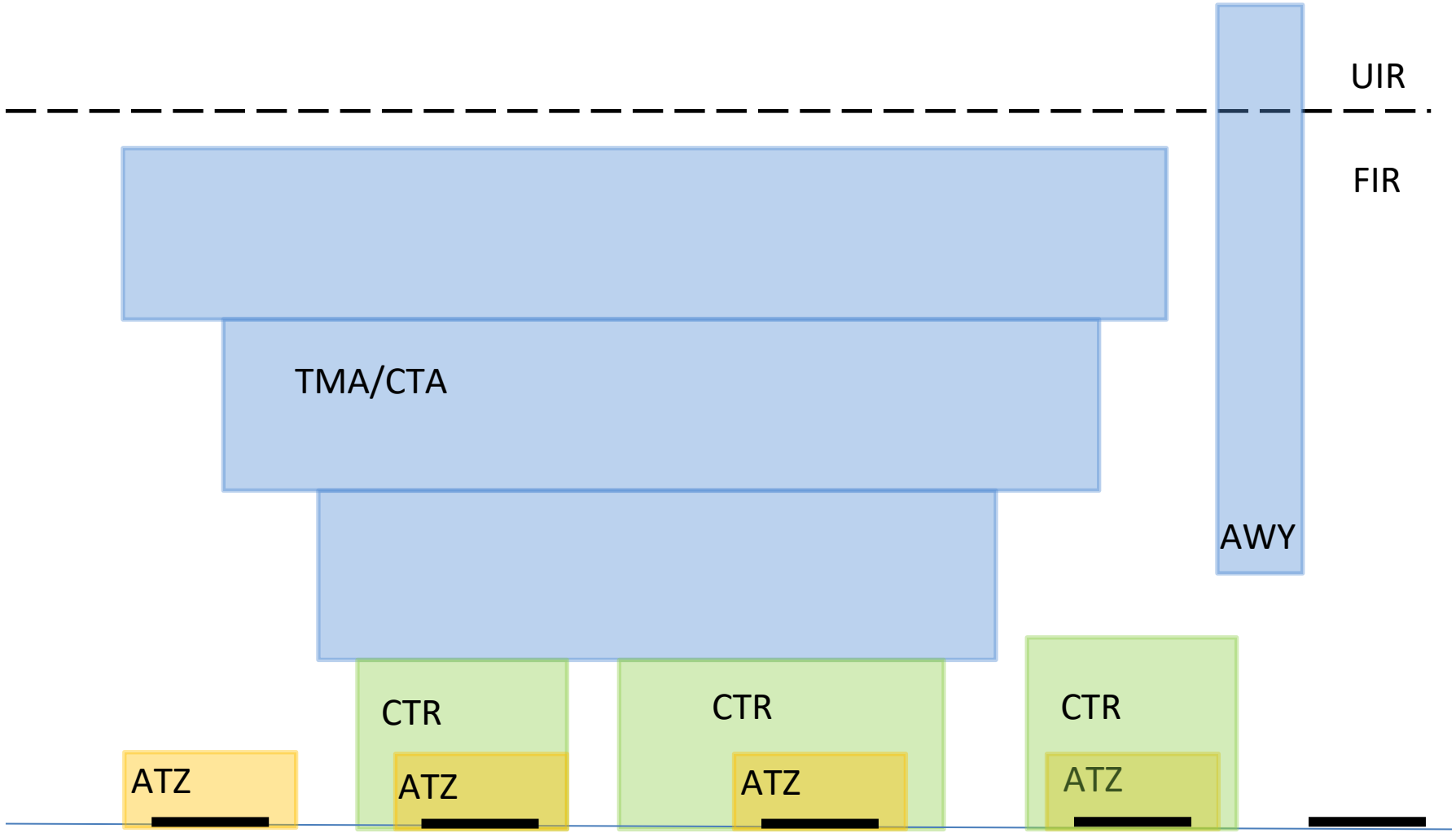
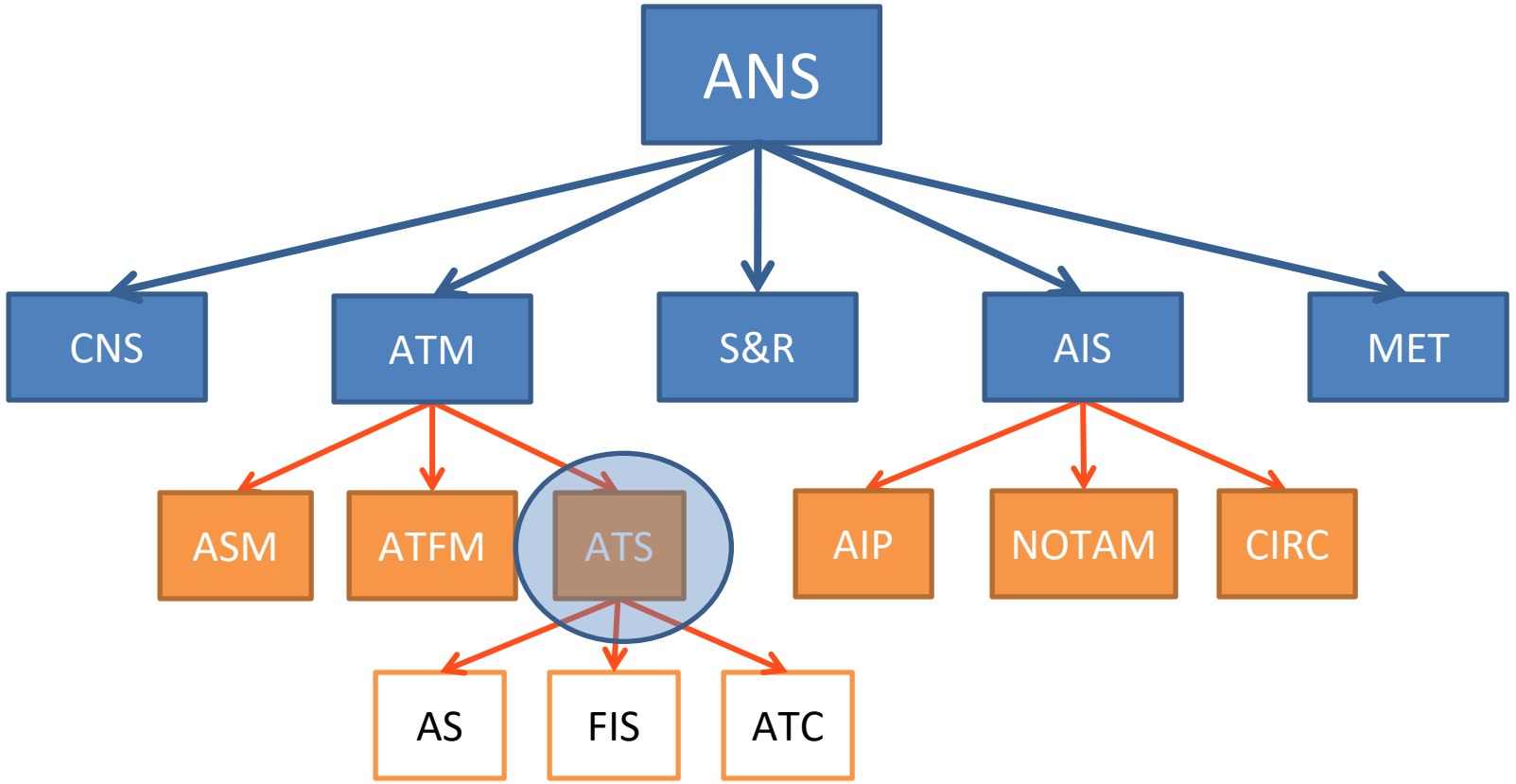


Air Traffic Services



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Air Traffic Services

Air Traffic Services Objectives

- Prevent collision between aircraft (air and ground)
- Expedite and maintain an orderly flow of air traffic

ATC

- Provide advice and information useful for the safe and efficient conduct of flights

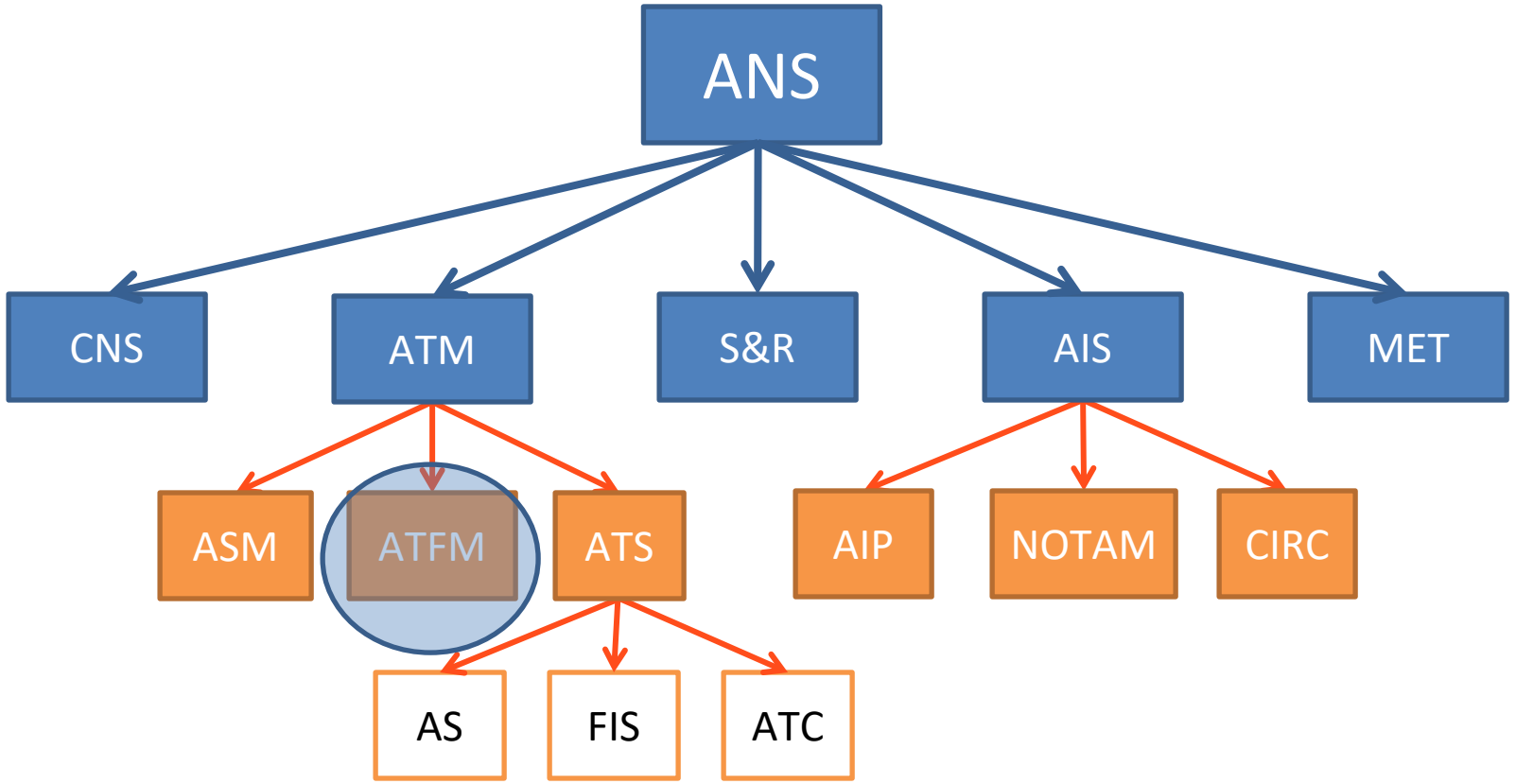
FIS

- Notify appropriate organisations regarding aircraft in need of search and rescue aid, and assist such organisations as required

AS

ICAO Annex 11: Air Traffic Services
ICAO Doc. 4444: Procedures for Air Navigation Services: Air Traffic Management.

Air Traffic Flow Management



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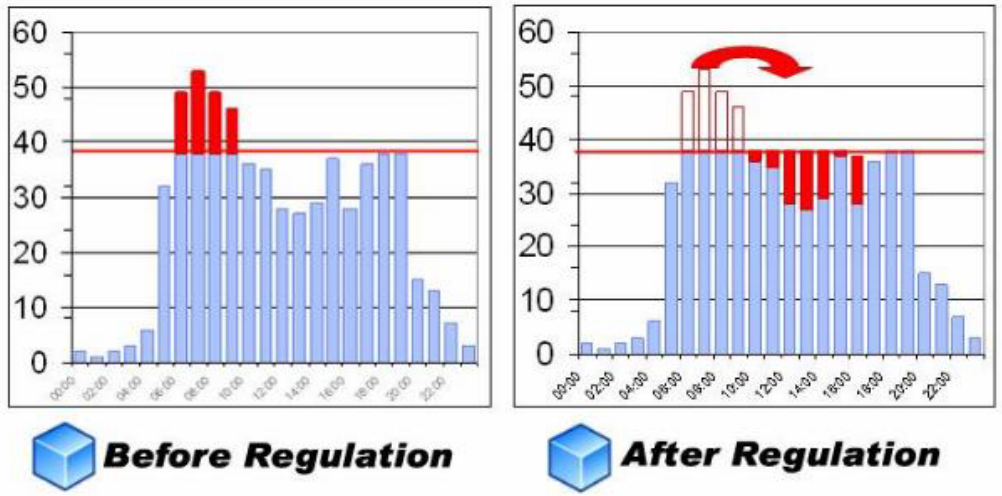
Air Traffic Flow Management

- **ATFM: Air Traffic Flow Management**
  - Additional service to ATS aiming at improving safety, throughput and efficiency

- **ATFCM: Air Traffic Flow and Capacity Management**
  - ATFM + aiming at using as much as possible ATS capacity
  - Keep **forecast demand**[1] below **estimated capacity** at **airports** and **airspace** sectors

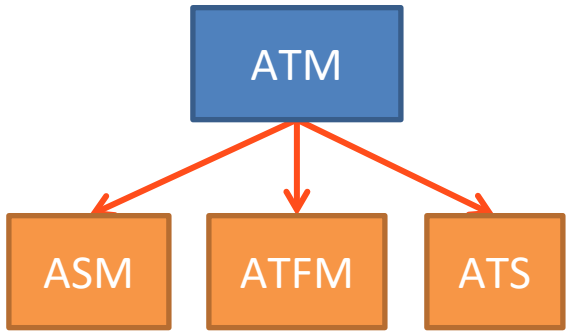


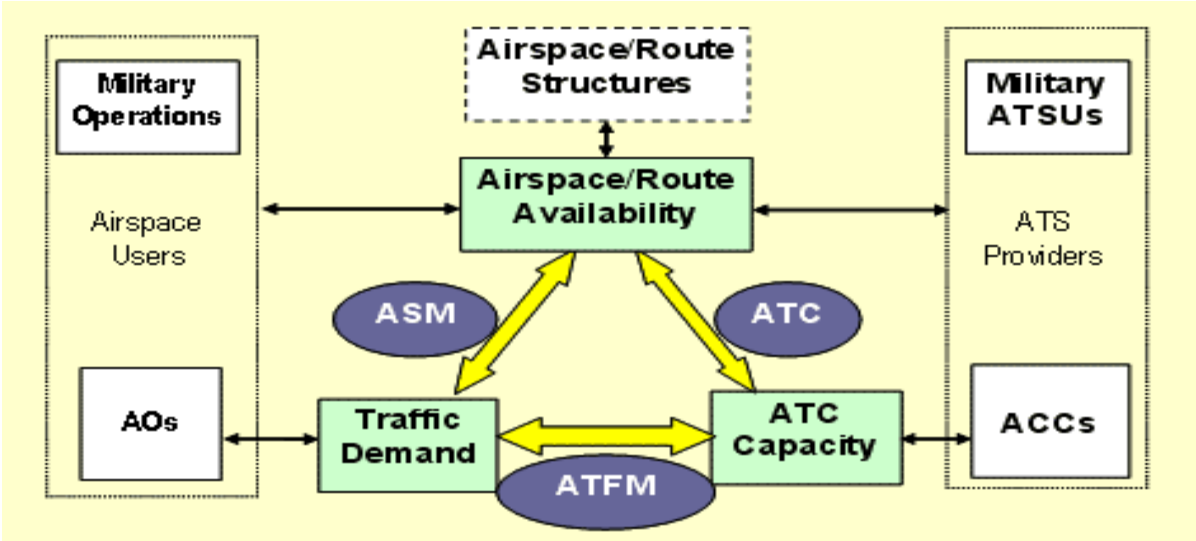
[1] Due to their easier predictability, for ATFM purposes, only IFR flights are considered when computing demand forecasts

Air Traffic Flow Management

- **Additional objectives**
  - Management of network systems infrastructure
  - Monitoring of network operations
  - Keep the Network Operations Plan updated
  - Network capacity optimisation
  - Maximise use of available resources and coordination (CDM)

Air Traffic Flow Management





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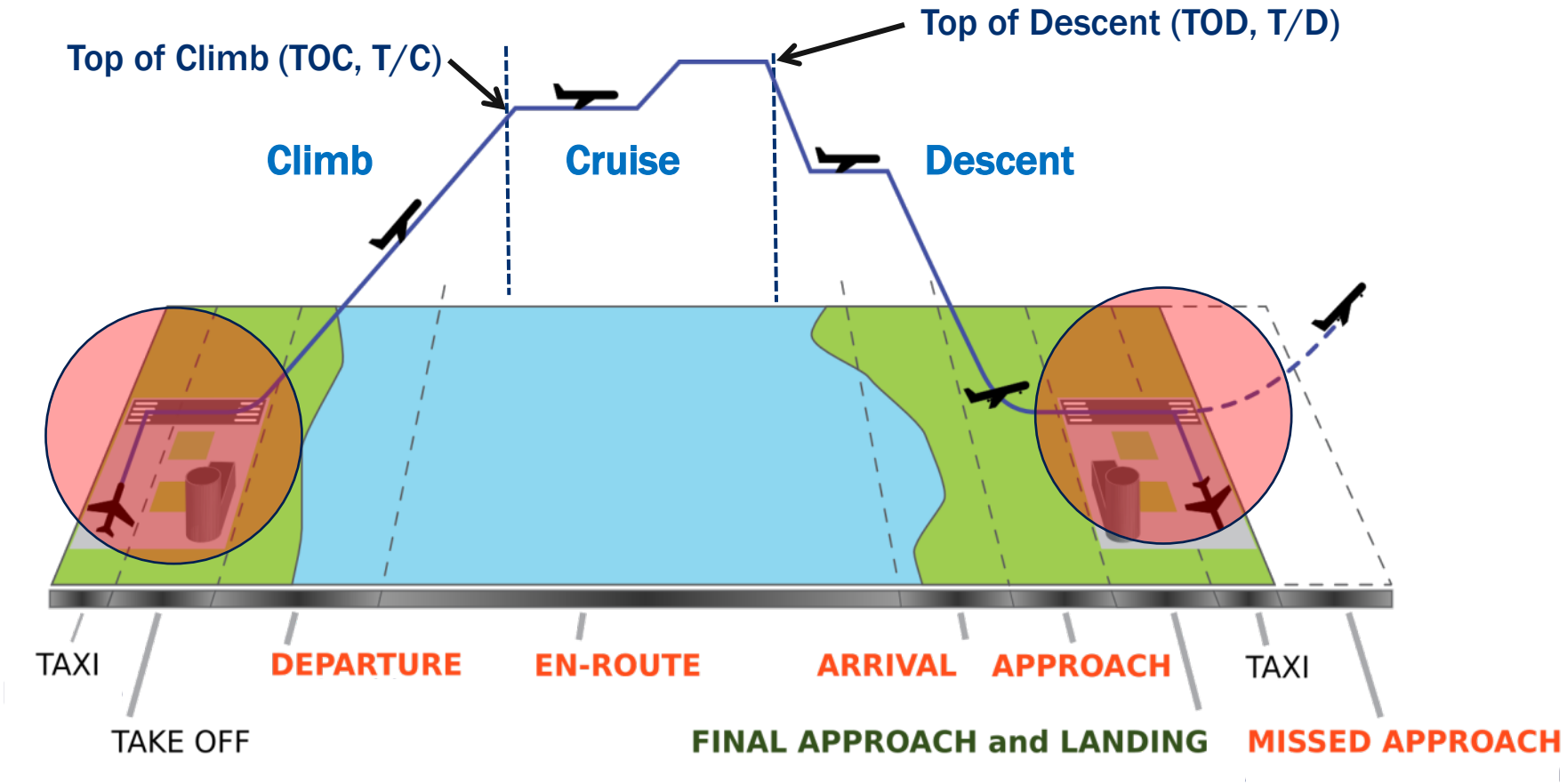
Capacity and demand imbalance

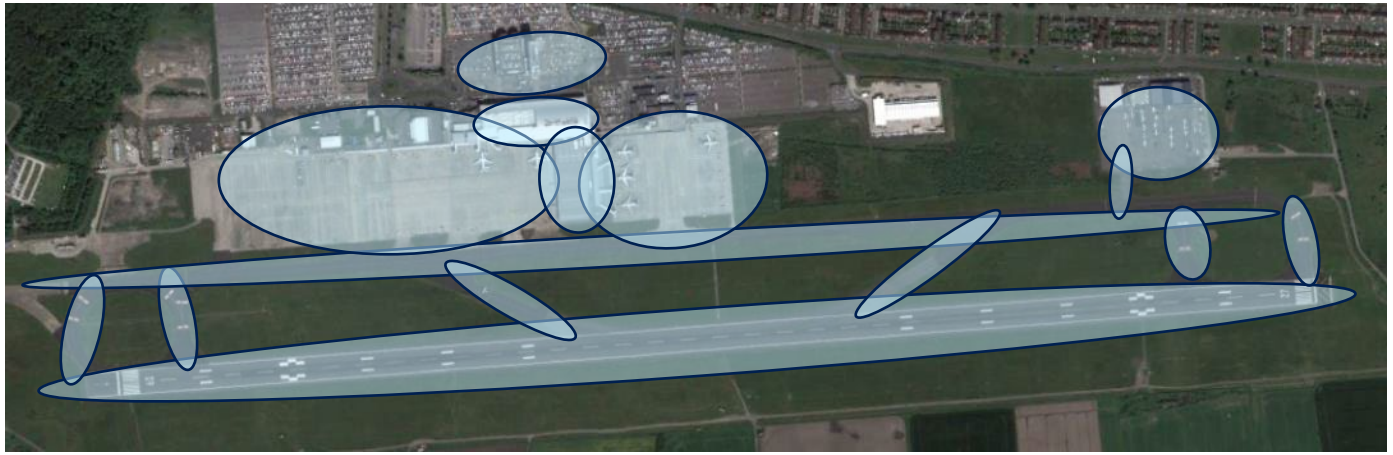
- Capacity problem – Airport
- Capacity problem – Airspace

Capacity and demand imbalance



Airports

- **Airport as a system of systems**
  - Runways
  - Taxiways
  - Apron stands
  - Passenger and cargo terminals
  - Ground access complexes



Airports

- **Airport as a system of systems**
  - Runways
  - Taxiways
  - Apron stands
  - Passenger and cargo terminals
  - Ground access complexes
- **Each one has its own capacity limitations**
- **Capacity at airport limited by most limiting subsystem**
- **BUT, at major airports:**
  - Capacity of system of **runways = most restricting element**

It is usually possible to increase capacity of the other airport elements, but
adding a new runway (+ associated taxiways) is very expensive & takes a very long time

Airports

- **Runway capacity**
  - **Principal cause, of most extreme instances of delays**
    → schedule disruptions, flight cancellations and missed connections
  - Varies greatly from day to day and its changes are difficult to predict (even a few hours in advance)
  - Cannot be avoided.

- This creates an **unstable operating environment**

Airports

- **Difference between**
  - Strategic airport capacity
  - Pre-tactical airport capacity
  - Tactical airport capacity

Airports

- **Strategic** airport capacity (scheduling at airports)
  - Three levels of airports
    - Level 1: **Non-coordinated airport** (capacity/demand ok)
    - Level 2: **Schedules facilitated airport** (capacity/demand imbalance at time periods)
    - Level 3: **Coordinated airport** (must have allocated slot to operate)

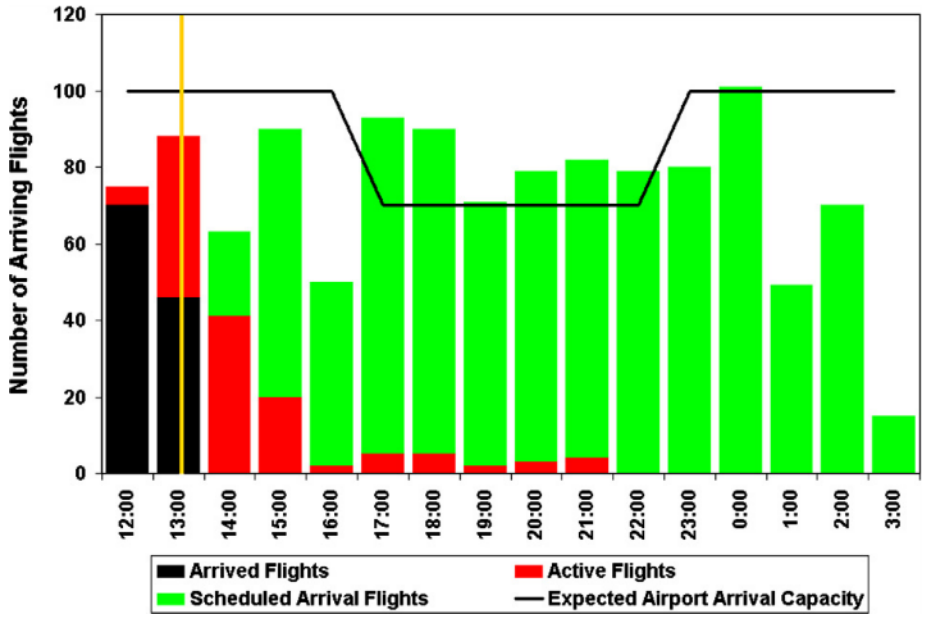
US	Europe
2 airports Level 3 (JFK) 6 airports Level 2 (EWR, LAX, MCO, ORD, SEA, SFO) Use of Special Traffic Management Programs	100 airports Level 3 70 airports Level 2

US – Europe comparison of Air Traffic Management related operational performance (Ed. 2018)

https://transport.ec.europa.eu/transport-modes/air/airports/slots_en

Airports

- **Pre-tactical** airport capacity



https://www.eurocontrol.int/article/what-is-a-slot

B. Manley and L. Sherry, "The Impact of Ground Delay Program (GDP) Rationing Rules on Passenger and Airline Equity", 3rd International Conference on Research in Air Transportation, ICRAT 2008, Fairfax, VA, June 01-04, 2008

Airports

- **Tactical** airport capacity

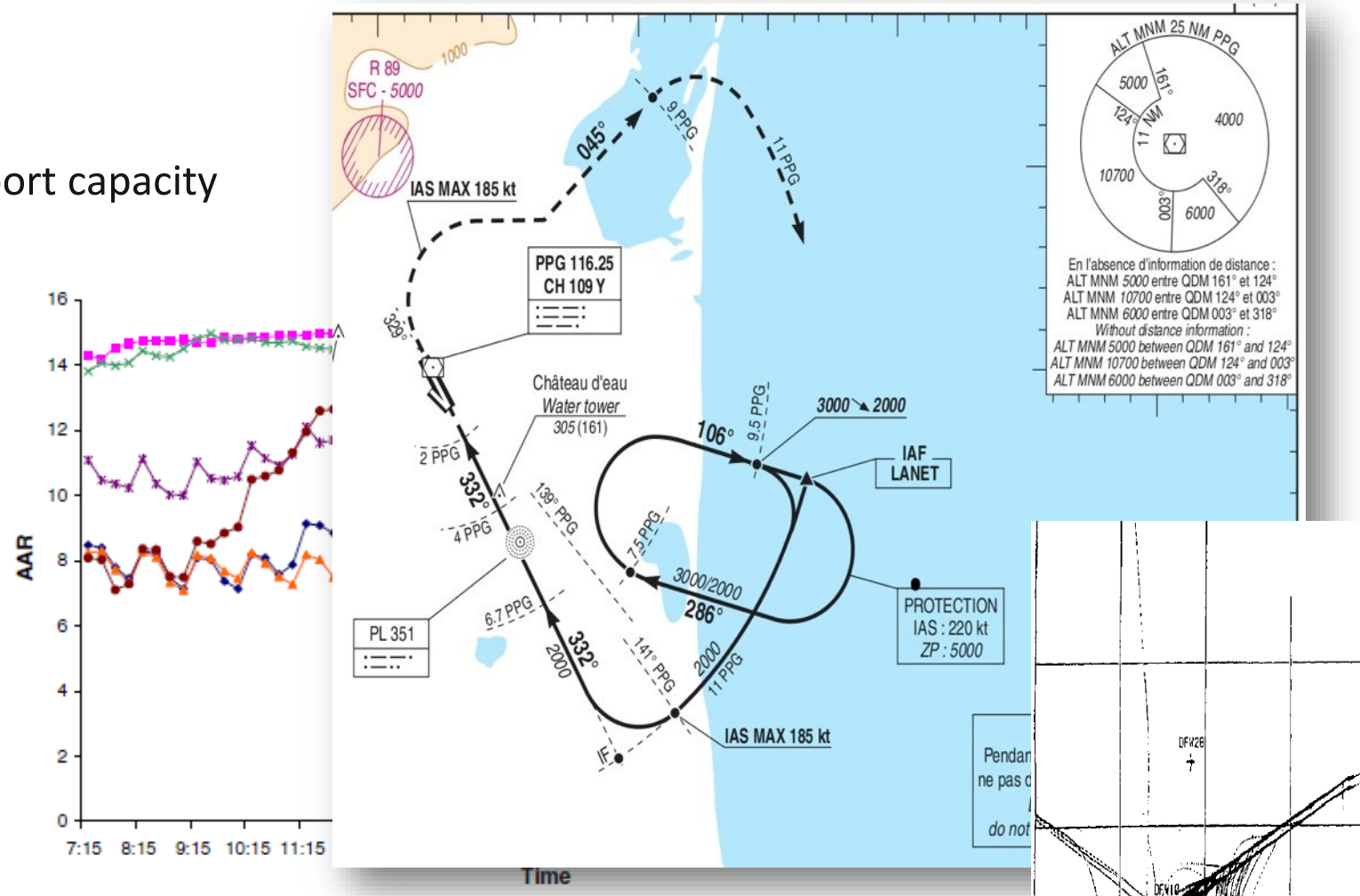
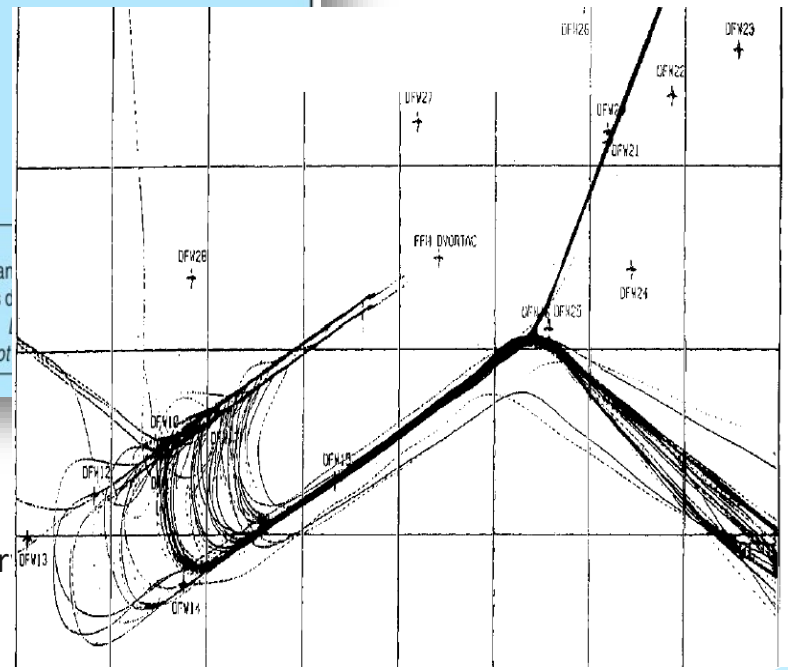


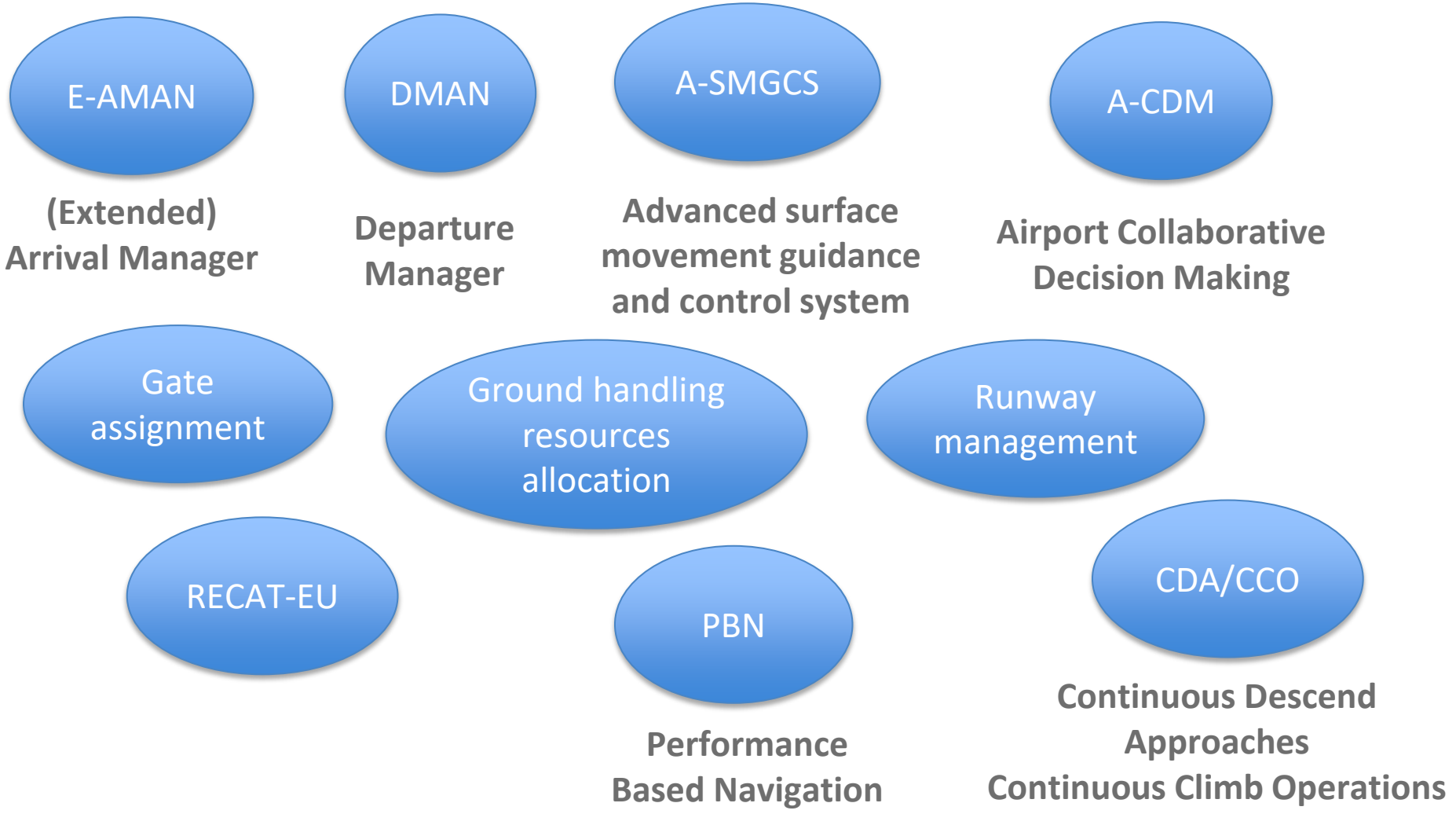
Fig. 6. Scenarios at SFO.



P.B. Liu, M. Hansen and A. Mukherjee, "Scenario-based air traffic flow management: From theor
Vol. 42, 2008, p.p. 685-702.

Airports

- Example some systems/problems to manage operations at airports (and vicinity)



Capacity and demand imbalance

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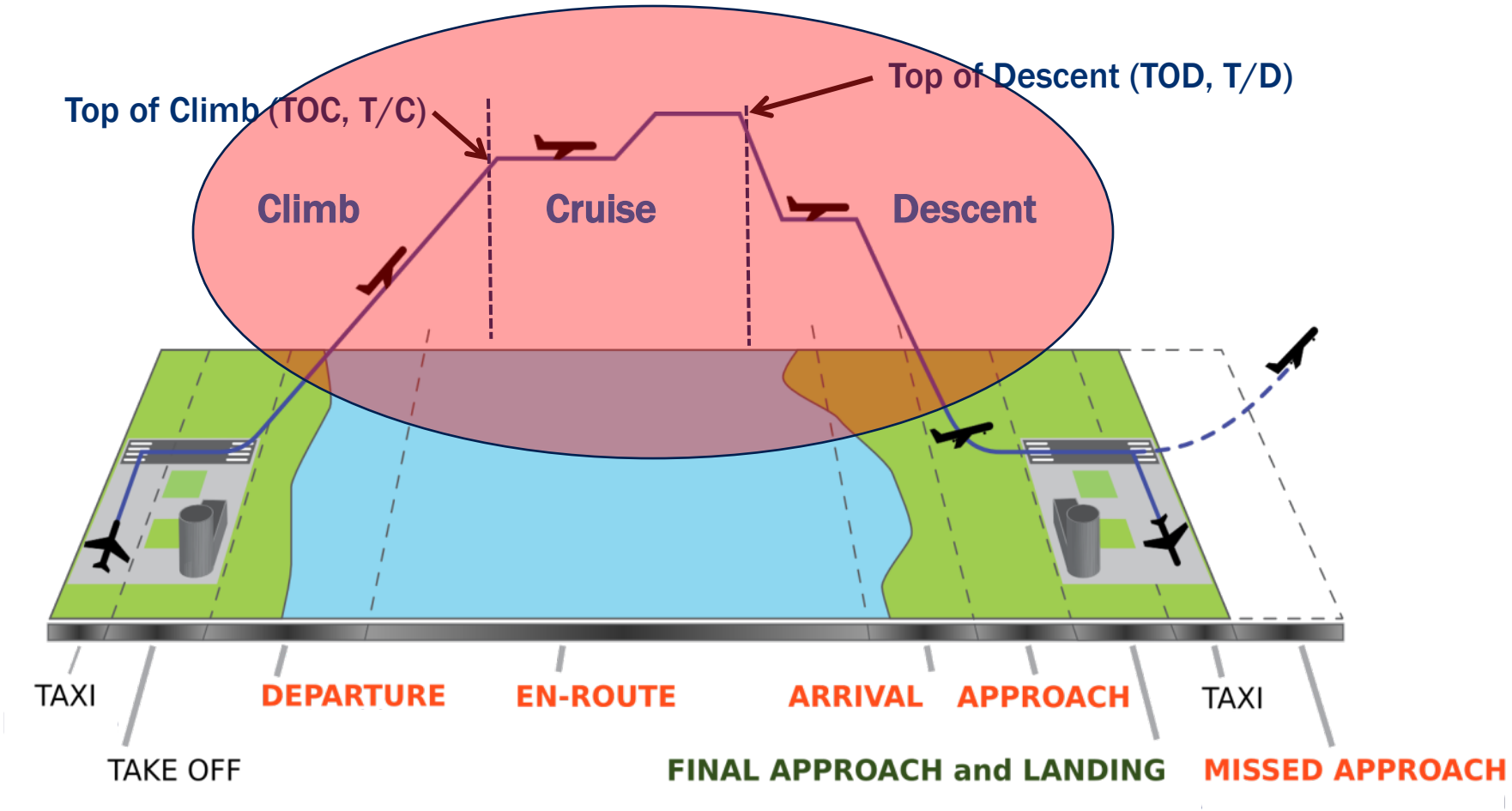
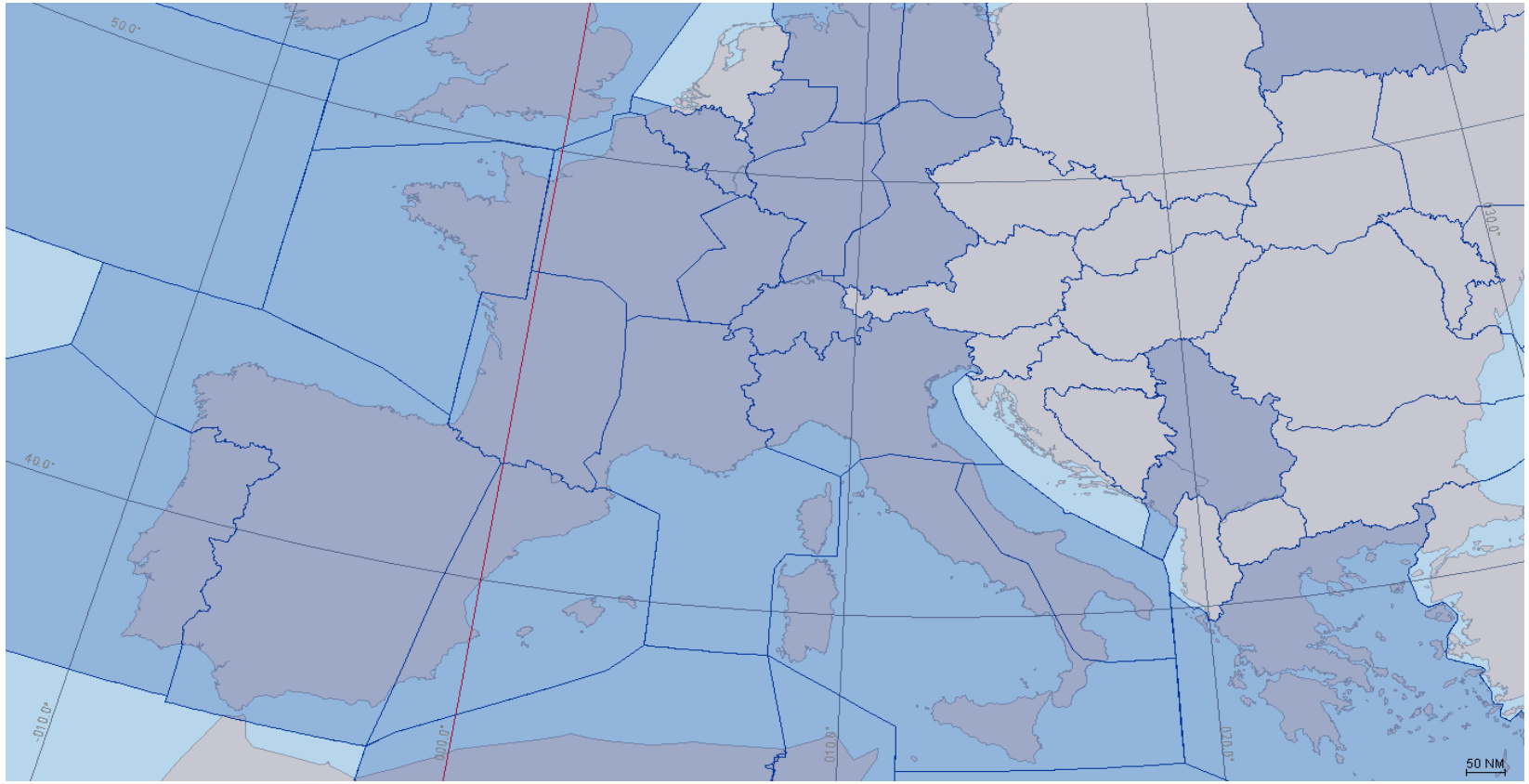


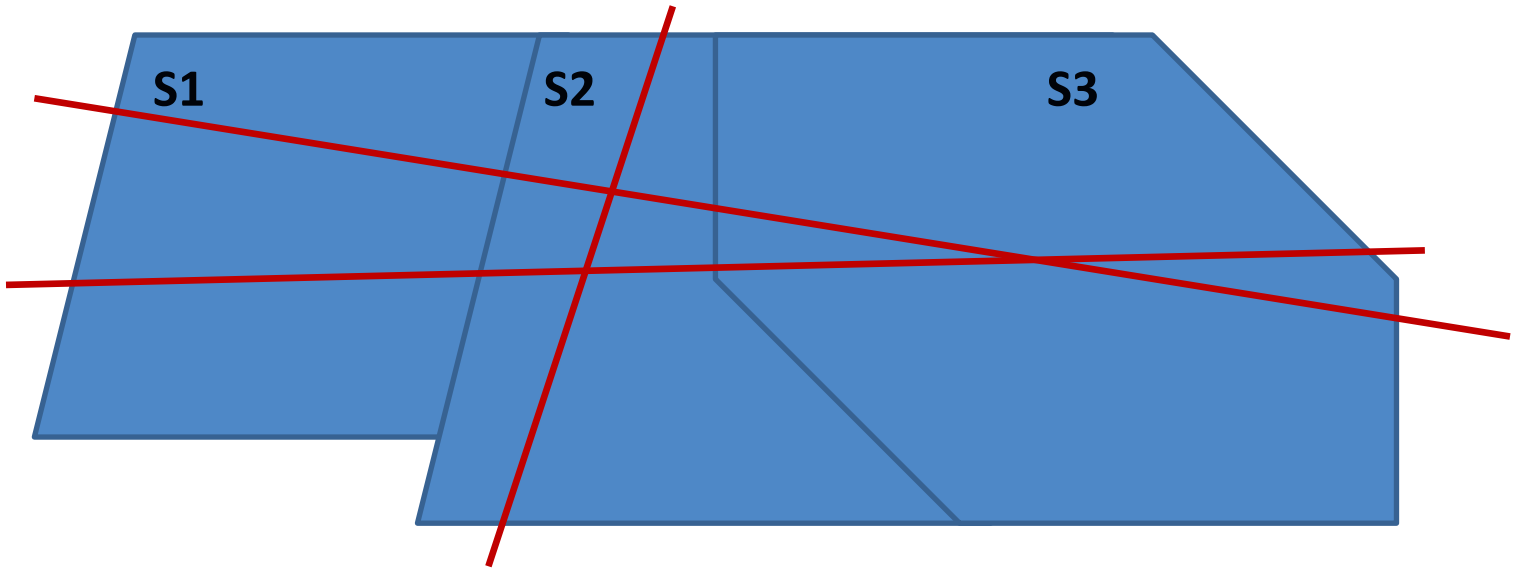
Airspace

- **Flight Information Regions (FIR) / Upper Information Regions (UIR)**



Airspace

- **Air Traffic Control**
  - Volume of airspace under the **responsibility** of one **controller** (usually helped by one or two extra controllers)
  - A radio communications **frequency** is assigned to each different sector
  - "**Hand off**" and "**Hand over**": Transfer of aircraft responsibility between controllers of adjacent sectors



Airspace

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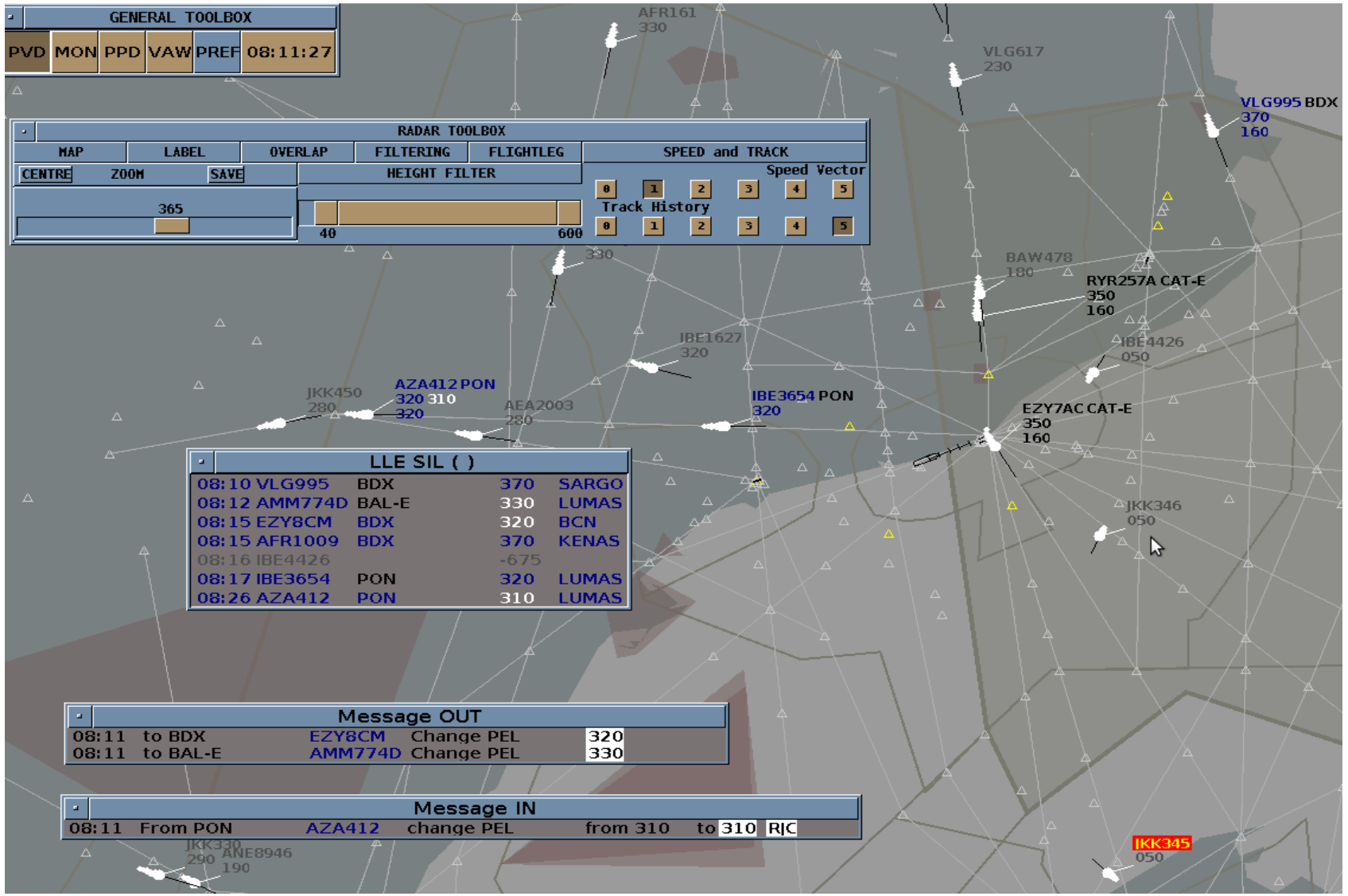
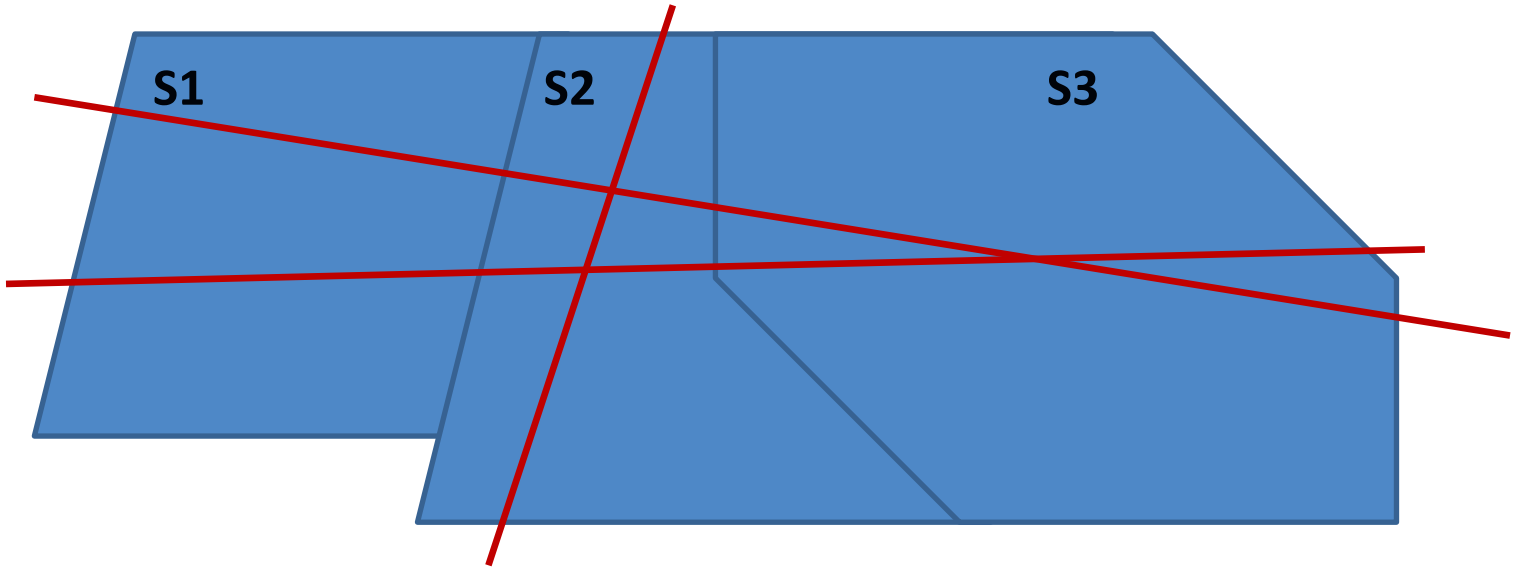


Airspace

- **Controller workload**
  - Principal constraint on airspace capacity
- Capacity might be reduced significantly in presence of severe weather
- Controller workload is difficult to compute
  - Capacity defined as number of aircraft simultaneously in sector or number of aircraft crossing sector per unit of time



Airspace

- **Numerous factors affect complexity of controllers' task**
  - Airspace factors
  - Traffic factors
  - Operational constraints

Airspace

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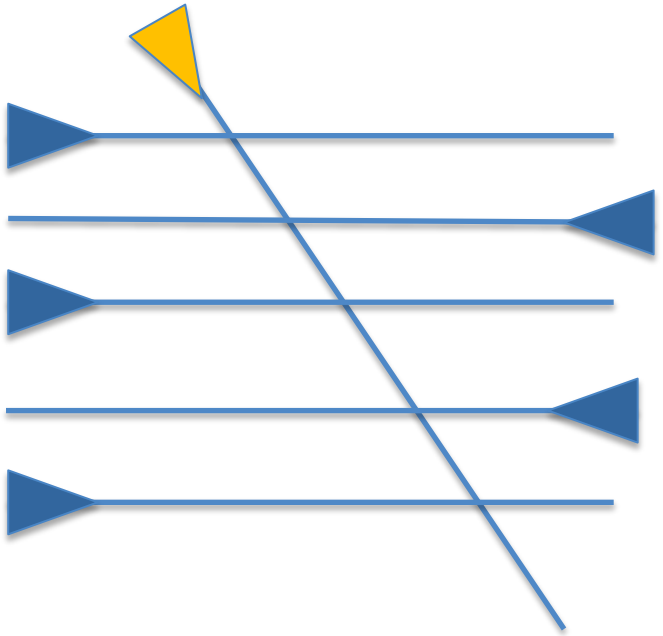
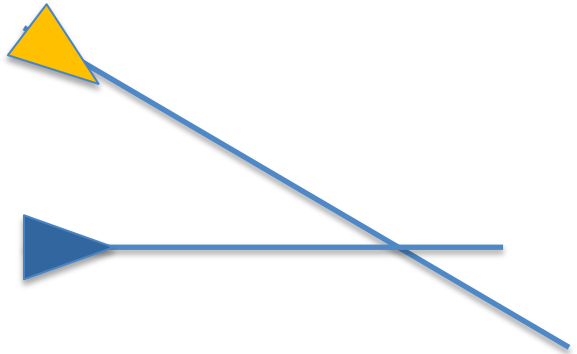
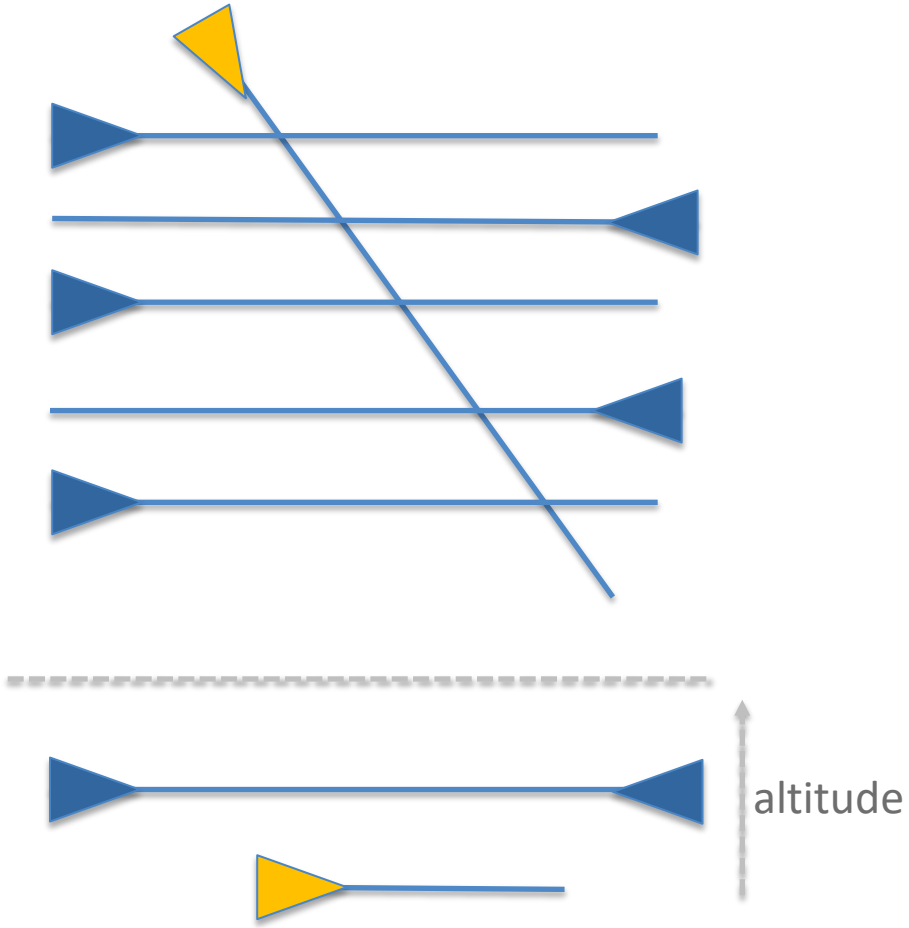


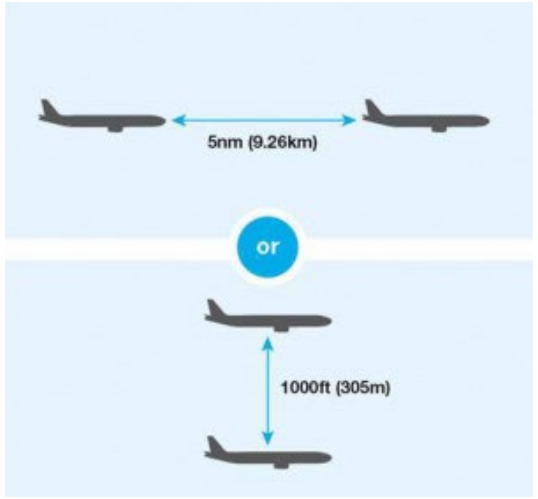
Airspace

- **Numerous factors affect complexity of controllers' task**
  - Airspace factors
  - Traffic factors
  - Operational constraints

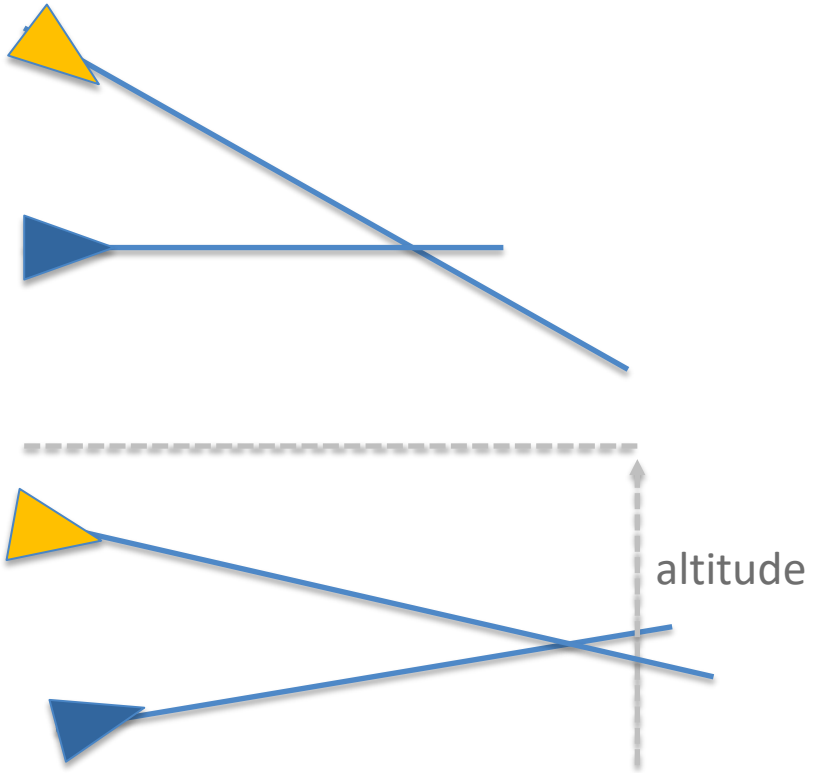


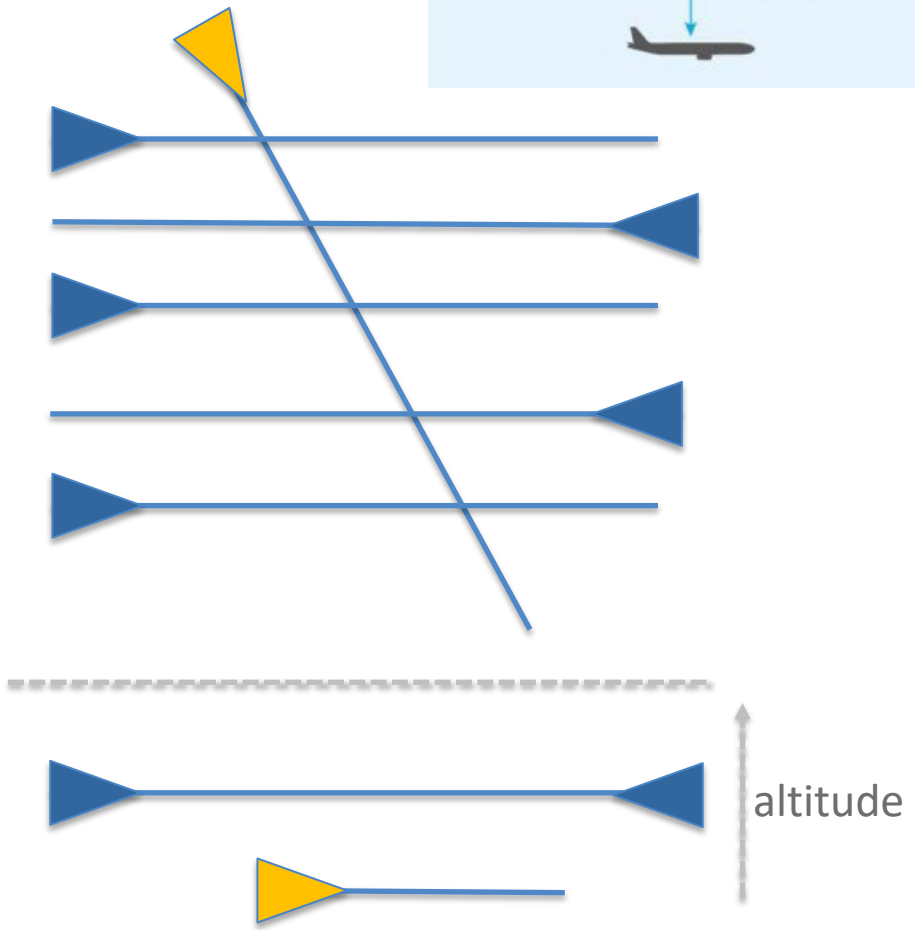


Airspace



- **Numerous factors affect complexity of controllers' task**
  - Airspace factors
  - Traffic factors
  - Operational constraints





Airspace

- **Airspace constraints typically have less severe effect on airline operations than airport constraints** (especially true in US)

→ A capacity-constrained en-route sector can often be by-passed by selecting an alternative route,

whereas a flight has no choice at its destination airport

Airspace

- **Airspace sectors capacity**

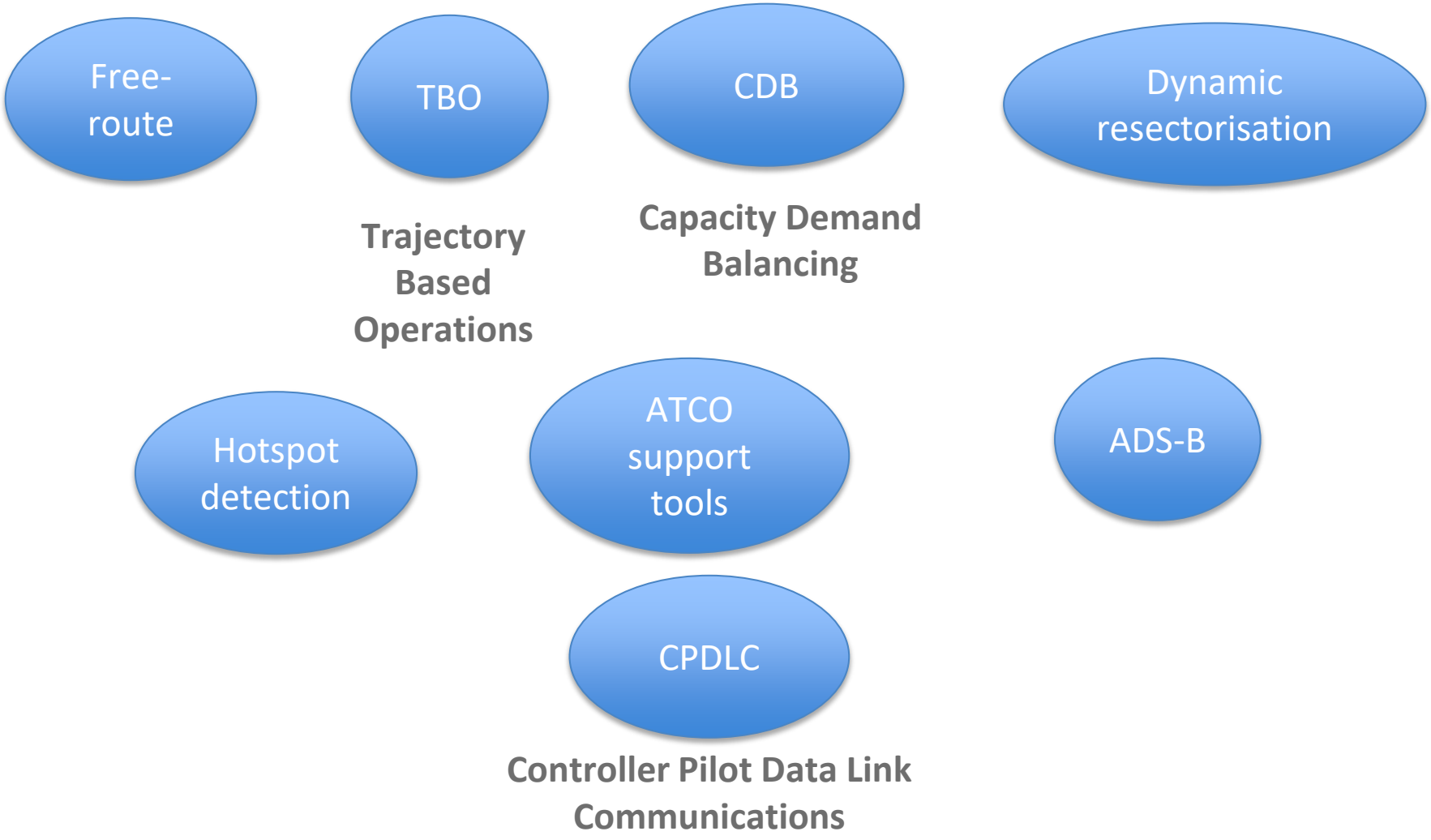
- principal constraint on **number of aircraft that can safely occupy a sector simultaneously**:
  - this number should be < 8–15
  - typically, number of aircraft scheduled to cross a sector during a 15-min time interval (in US en-route airspace < 15–20)
- capacity may be reduced significantly in presence of severe **weather**
- heavy dependence on **controller workload**

- difficulty to compute capacity of sector: in terms of either
  - number of simultaneously present aircraft or
  - number of aircraft crossing the sector per unit of time

Airspace

Transportation Research Laboratory

- Example some systems/problems to manage operations en-route



Air Traffic Management

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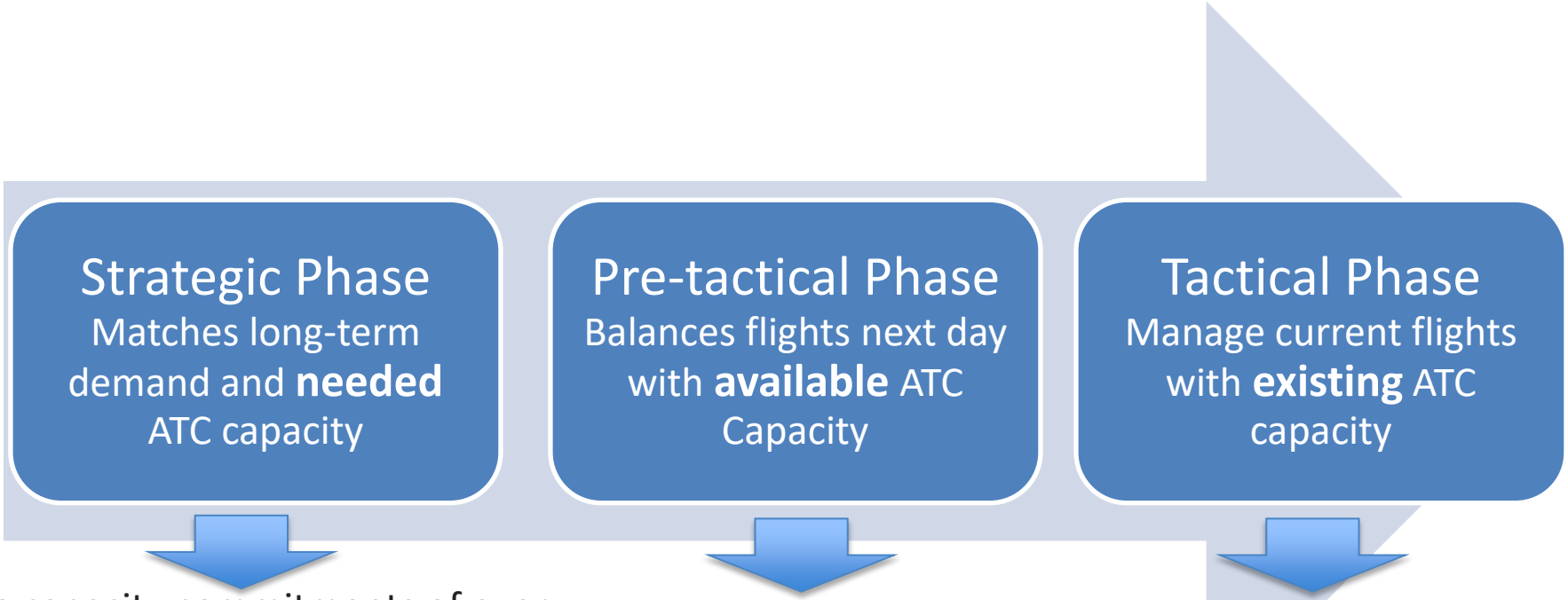


The capacity commitments of every operational stakeholder in the network are reflected in a common planning document: the **Network Operations Plan (NOP)**

Daily Plan of ATFCM measures on the NOP Portal

Tactical updates in the **NOP Portal**

Air Traffic Management

If demand exceeds capacity

1. Try to **increase capacity**

Sectors/Airport configuration

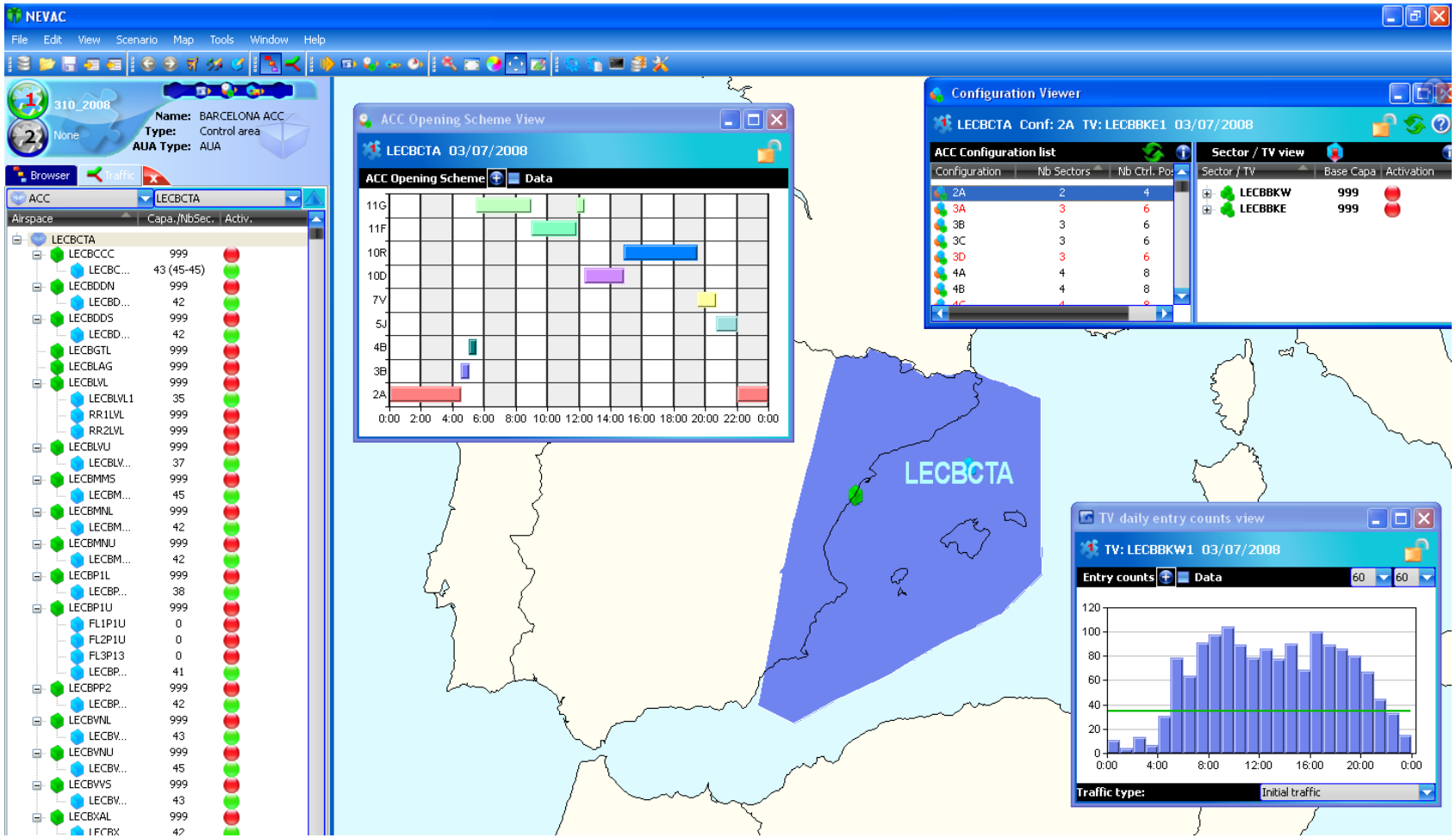
2. **Manage Flows (reduce demand)**

ATFM initiative (regulation)

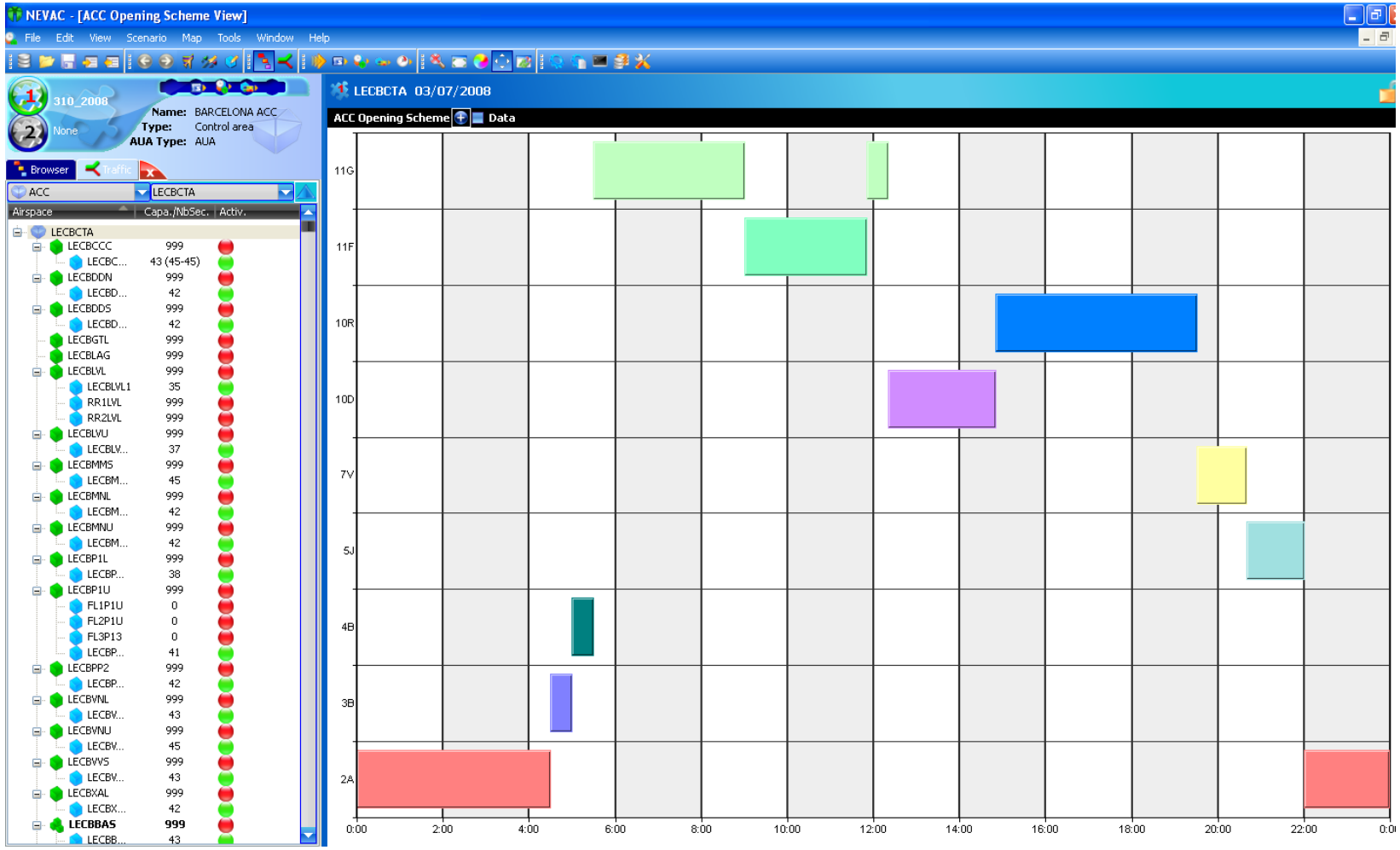
Air Traffic Management

Transportation Research Laboratory

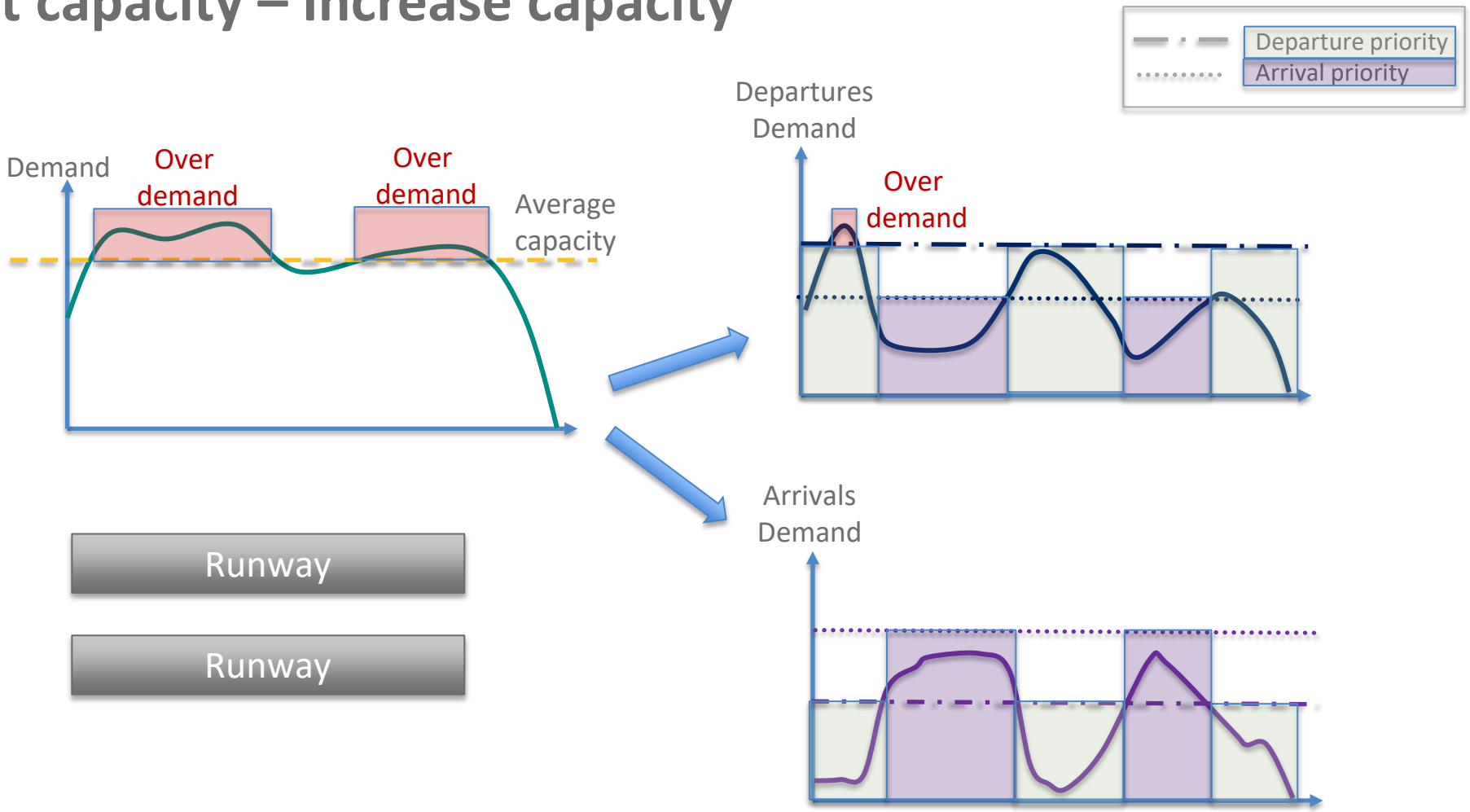
Airspace sectorisation – Barcelona FIR example



Airspace sectorisation – Barcelona FIR example



Airport capacity – Increase capacity



Air Traffic Management – ATFM initiatives

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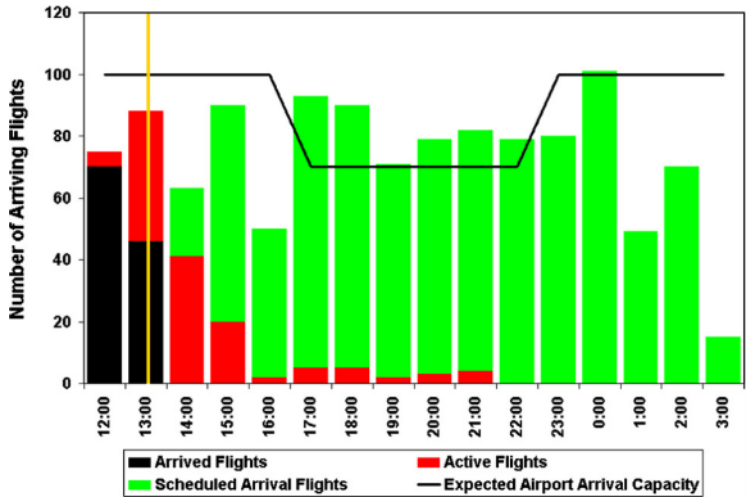
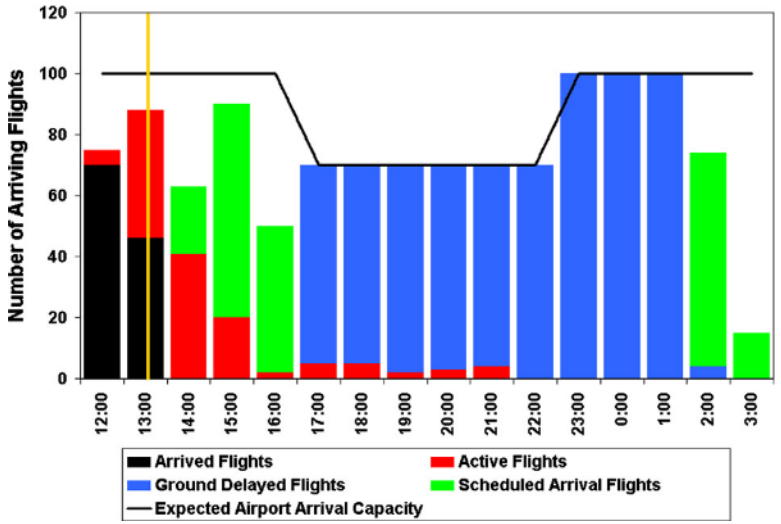
Demand management





B. Manley and L. Sherry, "The Impact of Ground Delay Program (GDP) Rationing Rules on Passenger and Airline Equity", 3rd International Conference on Research in Air Transportation, ICRAT 2008, Fairfax, VA, June 01-04, 2008

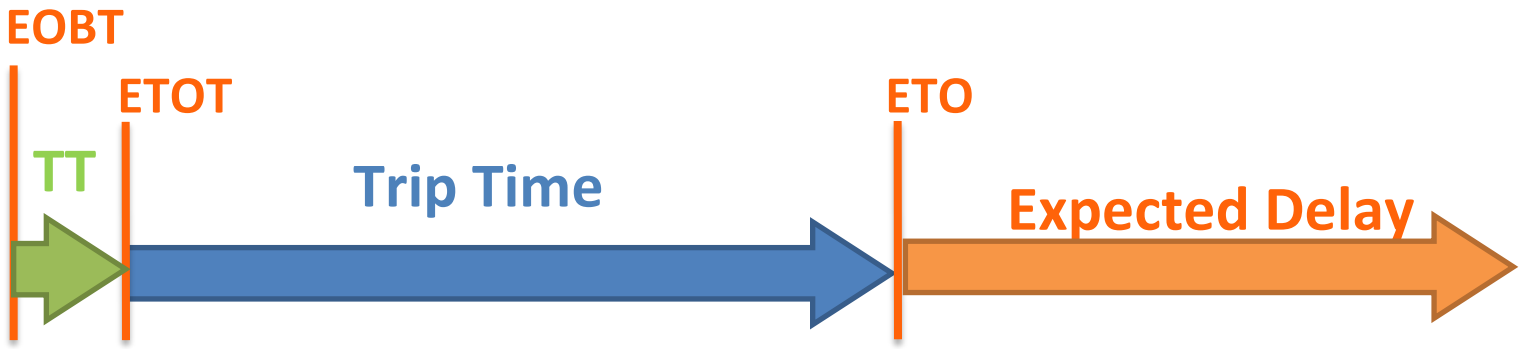
Air Traffic Management – ATFM initiatives

- If there is an imbalance between capacity and demand:
  - **Delay is needed**

- **If nothing is done, the delay will be in the air**
  - Re-routing to avoid congested areas
  - Holding at destination
  - → High fuel consumption

→ **Ground delay is a better approach**

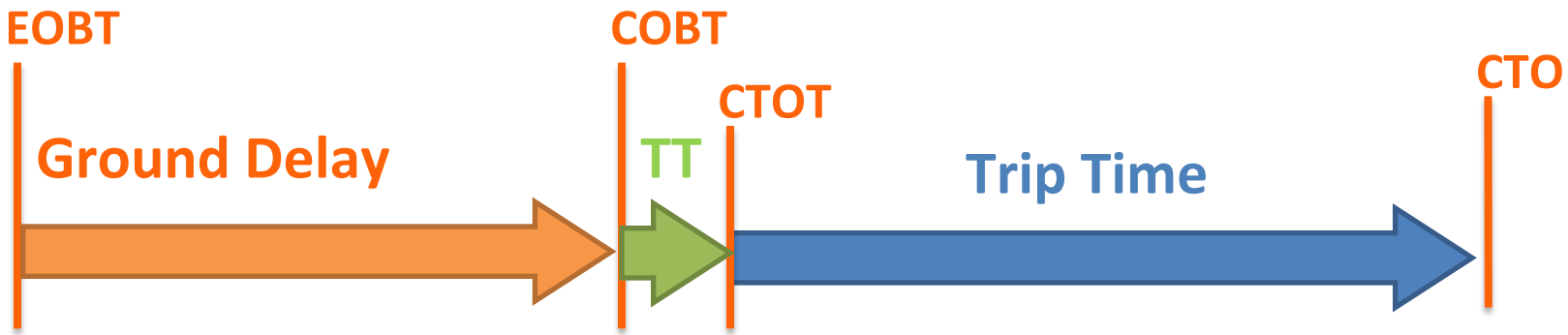
Air Traffic Management – ATFM initiatives



EOBT: Estimated Off-Block Time
ETOT: Estimated Take-Off time
ETO: Estimated Time Over
TT: Taxi Time

Air Traffic Management – ATFM initiatives

- Actual take-off time between [CTOT-5 min, CTOT + 10 min]
- TWR controllers will enforce take-off within the limits



EOBT: Estimated Off-Block Time
ETOT: Estimated Take-Off time
ETO: Estimated Time Over
TT: Taxi Time

COBT: Calculated Off-Block Time
CTOT: Calculated Take-Off Time
CTO: Calculated Time Over

Air Traffic Management – ATFM initiatives

- Computed Assisted Slot Allocation (CASA)
  - Slot allocation algorithm (example)

Flight	ETO
F1	10:00
F2	10:06
F3	10:07
F4	10:10
F5	10:12
F6	10:18

ETO computed based on flight schedule

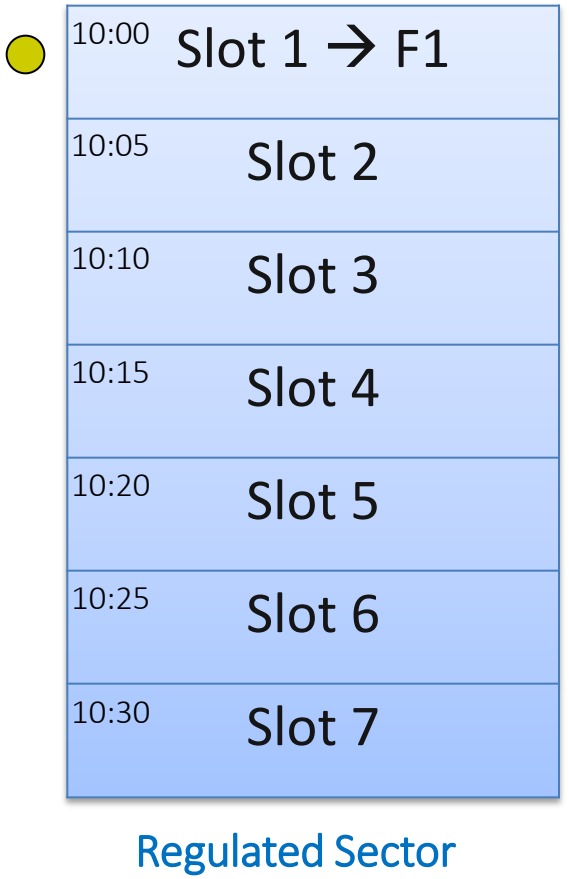
10:00	Slot 1
10:05	Slot 2
10:10	Slot 3
10:15	Slot 4
10:20	Slot 5
10:25	Slot 6
10:30	Slot 7

Regulated Sector

Air Traffic Management – ATFM initiatives

- Computed Assisted Slot Allocation (CASA)
  - Slot allocation algorithm (example)

Flight	ETO	Delay
F1	**10:00**	**0 min**
F2	**10:06**	
F3	**10:07**	
F4	**10:10**	
F5	**10:12**	
F6	**10:18**	



Air Traffic Management – ATFM initiatives

Flight	ETO	Delay
F1	10:00	0 min
F2	10:06	0 min
F3	10:07	
F4	10:10	
F5	10:12	
F6	10:18	

Air Traffic Management – ATFM initiatives

- Computed Assisted Slot Allocation (CASA)
  - Slot allocation algorithm (example)

Flight	ETO	Delay
F1	10:00	0 min
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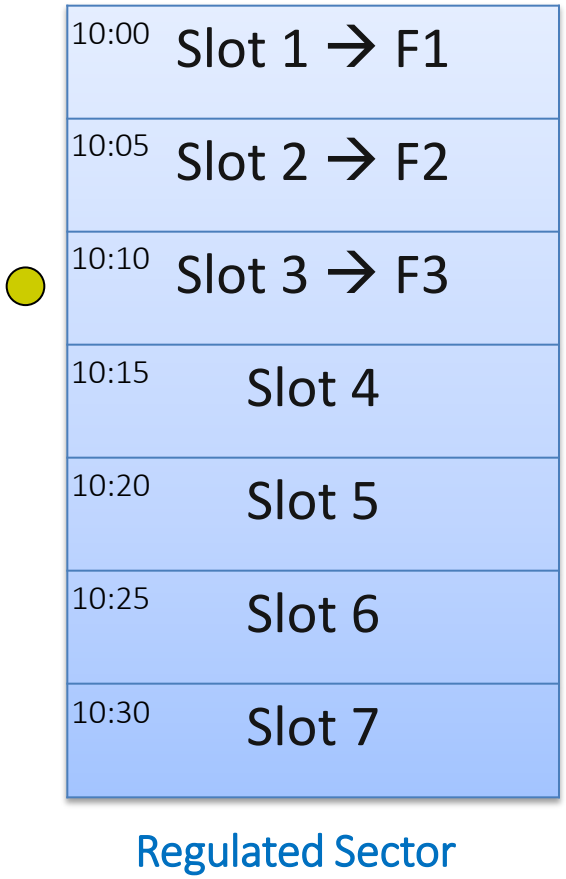
F3	10:07	
F4	10:10	
F5	10:12	
F6	10:18	

Air Traffic Management – ATFM initiatives

- Computed Assisted Slot Allocation (CASA)
  - Slot allocation algorithm (example)

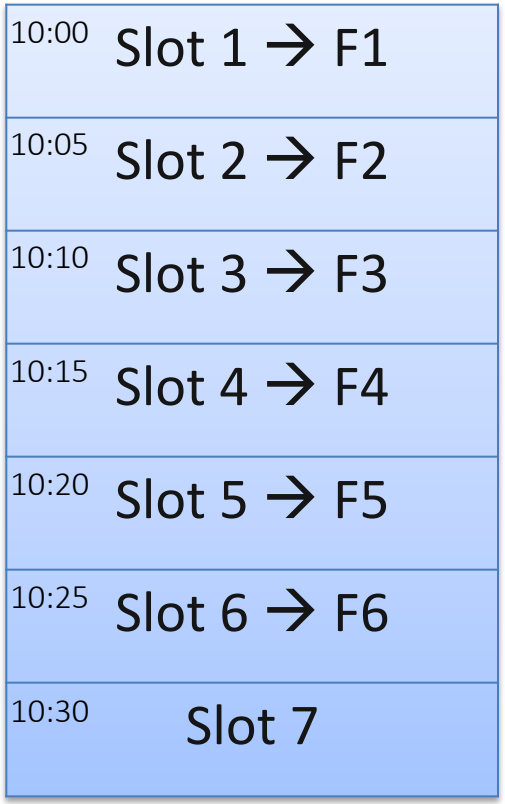
Flight	ETO	Delay
F1	10:00	0 min
F2	10:06	0 min
F3	10:07	3 min
F4	10:10	
F5	10:12	
F6	10:18	



Air Traffic Management – ATFM initiatives

- Computed Assisted Slot Allocation (CASA)
  - Slot allocation algorithm (example)

Flight	ETO	Delay
F1	10:00	0 min
F2	10:06	0 min
F3	10:07	3 min
F4	10:10	5 min
F5	10:12	8 min
F6	10:18	7 min

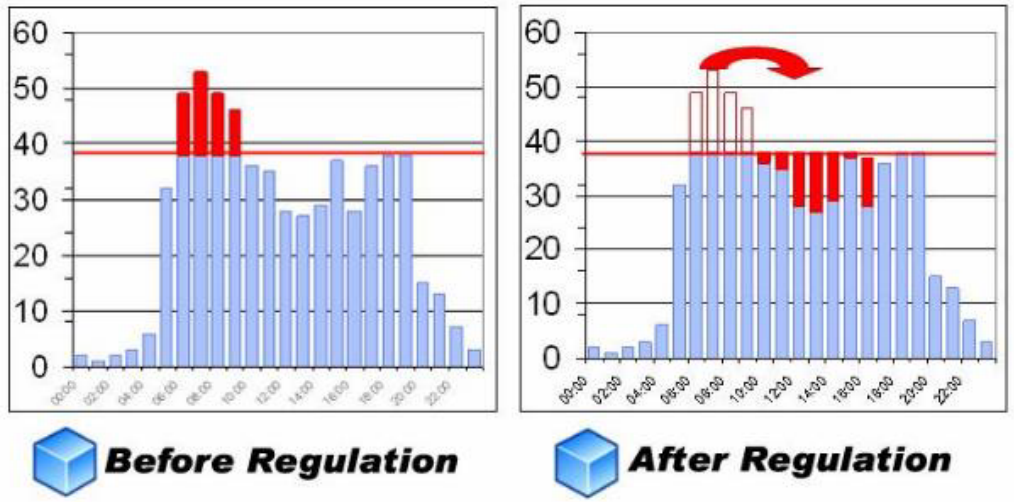


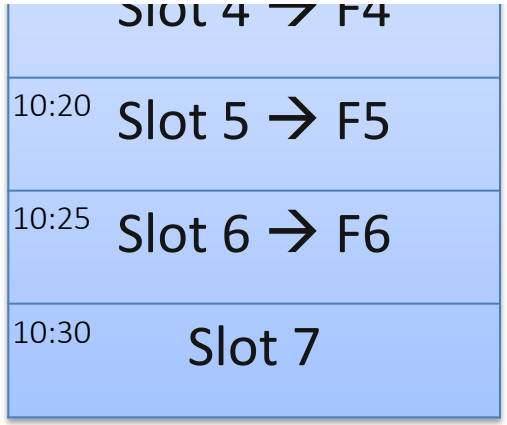
Regulated Sector

Air Traffic Management – ATFM initiatives

- Computed Assisted Slot A
  - Slot allocation algorith

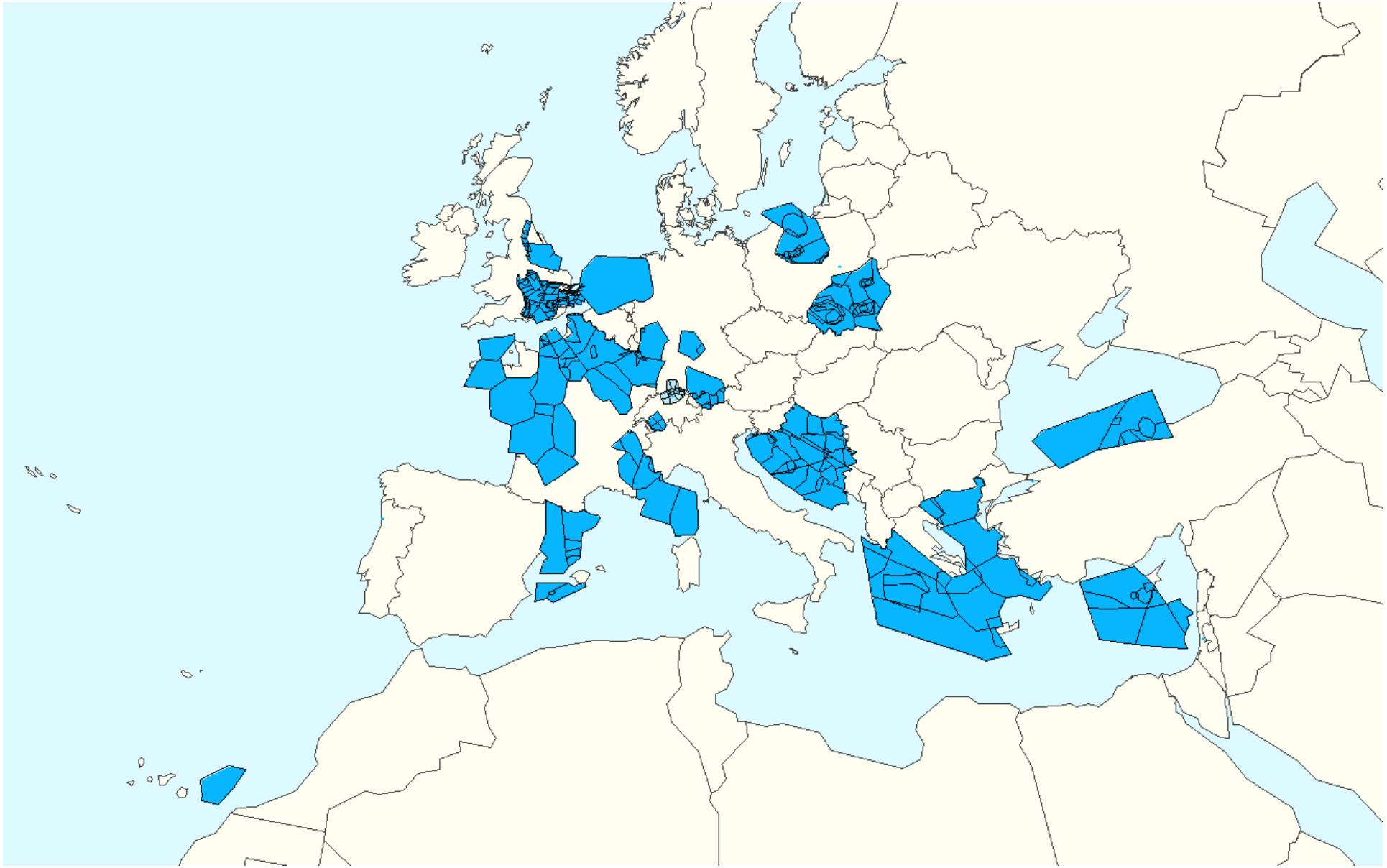
Flight	ETO	Delay
F1	10:00	0 mir
F2	10:06	0 mir
F3	10:07	3 mir
F4	10:10	5 min
F5	10:12	8 min
F6	10:18	7 min





Regulated Sector

Air Traffic Management – ATFM initiatives



Air Traffic Management – ATFM initiatives

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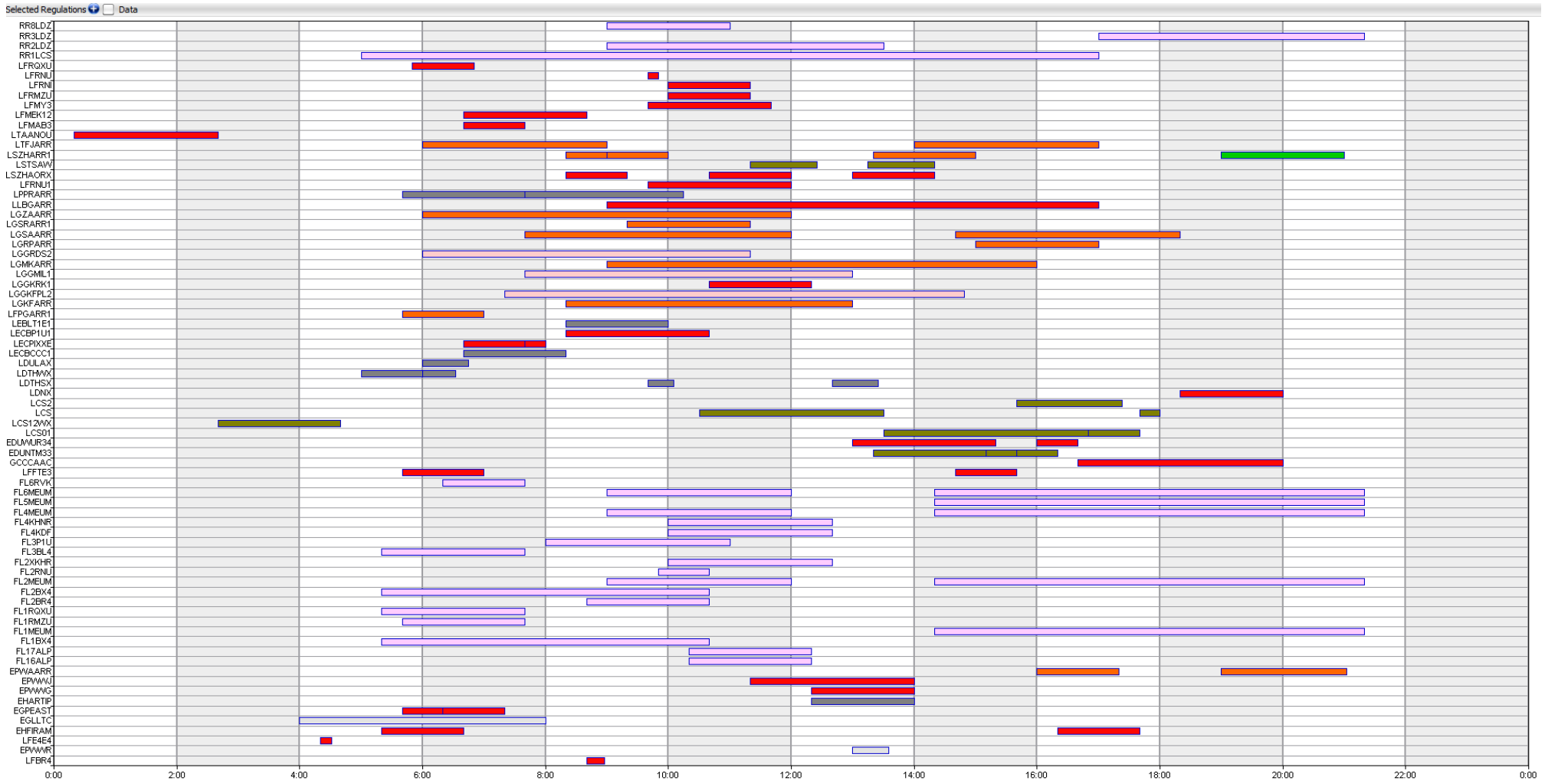
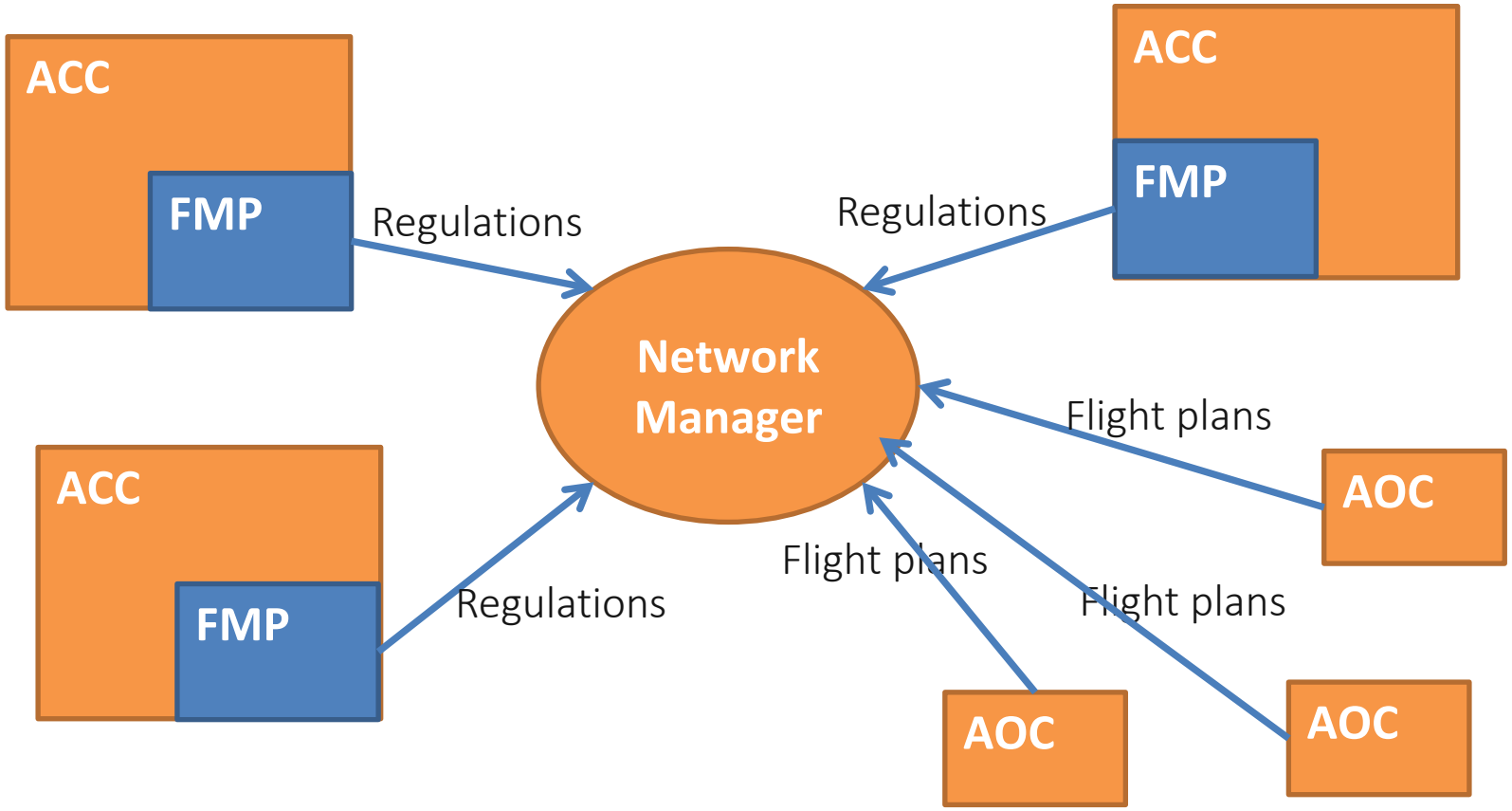


Air Traffic Management – ATFM initiatives

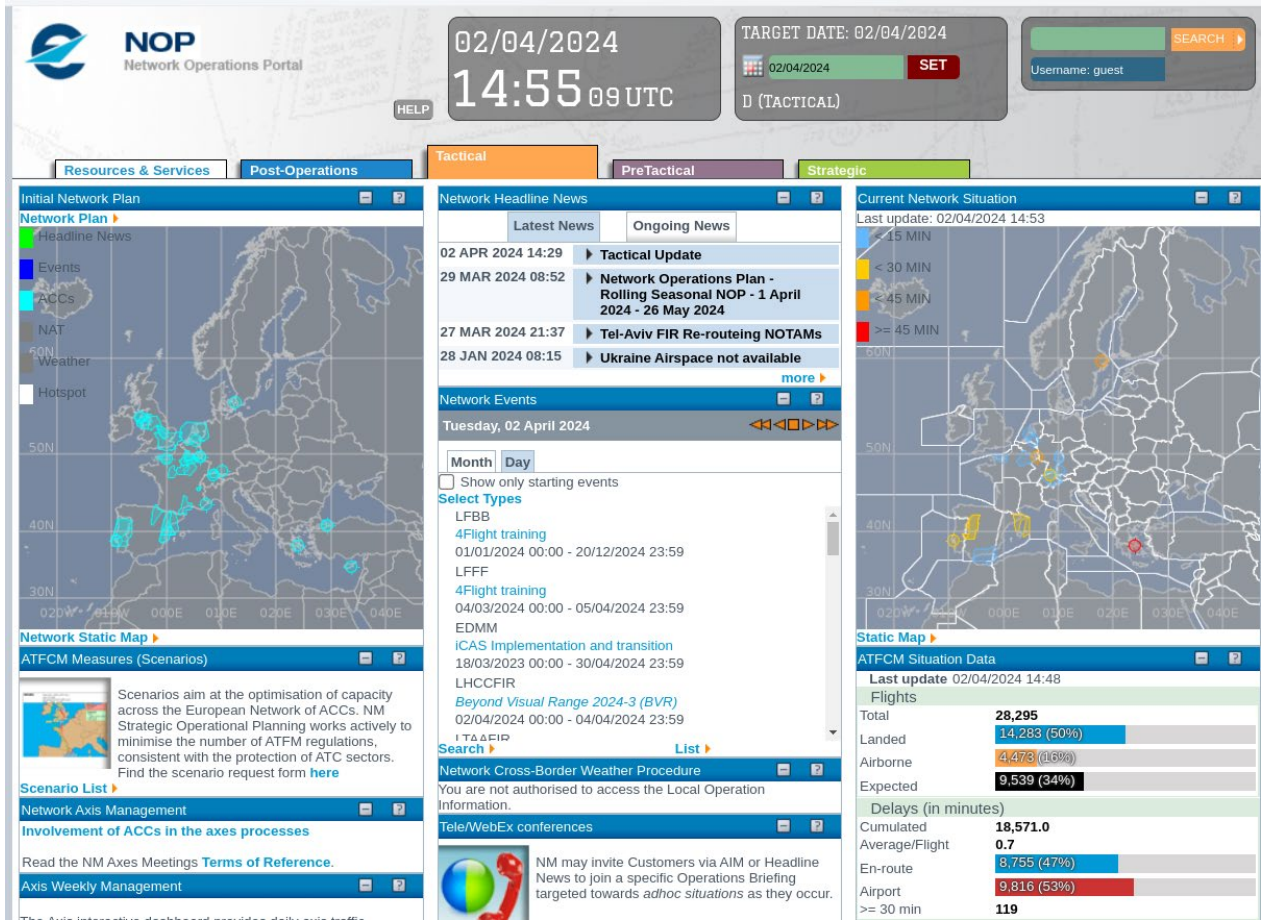
- Network Manager Operations Centre

ACC: Area Control Center
FMP: Flow Management Position
AOC: Airline Operating Center



Air Traffic Management – ATFM initiatives

- Network Operations Portal



http://www.public.nm.eurocontrol.int/PUBPORTAL/gateway/spec/index.html

Modelling considerations

Modelling considerations

- What should be considered in ATM modelling?

THE ROADMAP FOR DELIVERING HIGH PERFORMING AVIATION FOR EUROPE
European ATM Master Plan
Executive View Edition 2015

EUROPEAN ATM MASTER PLAN
Digitalising Europe's Aviation Infrastructure
Executive view
Edition2022

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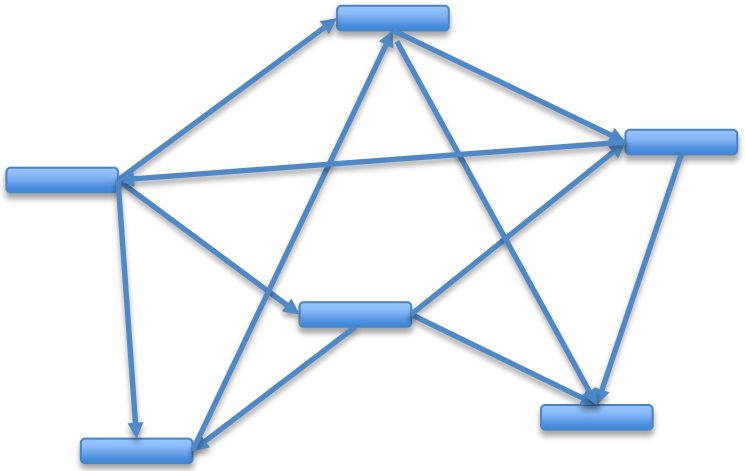
Modelling considerations

- What should be considered in ATM modelling?



Modelling considerations

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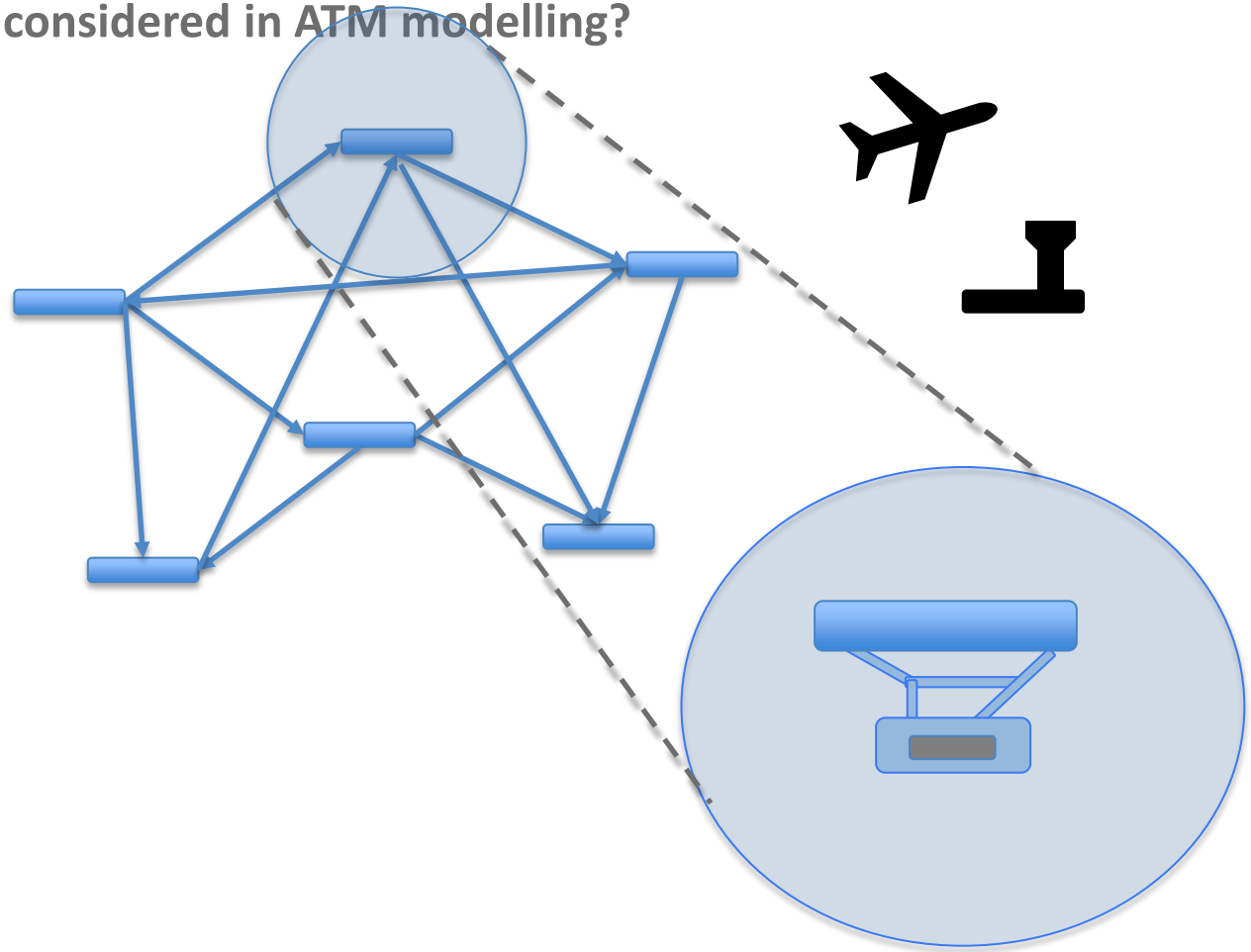
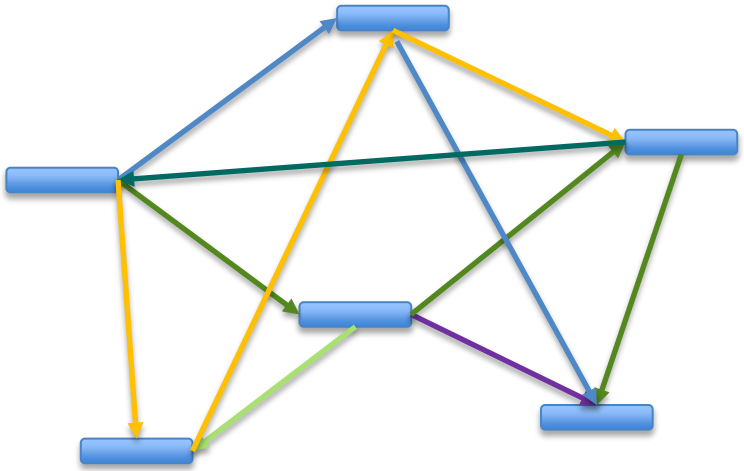
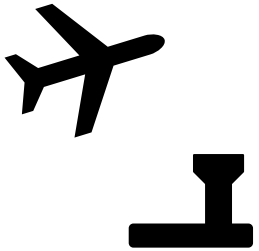
- What should be considered in ATM modelling?



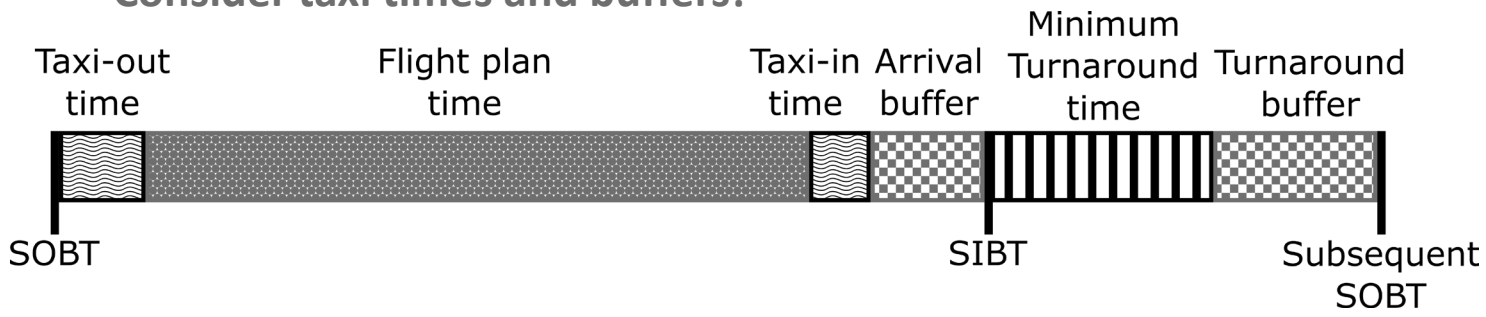
Modelling considerations

- What should be considered in ATM modelling?





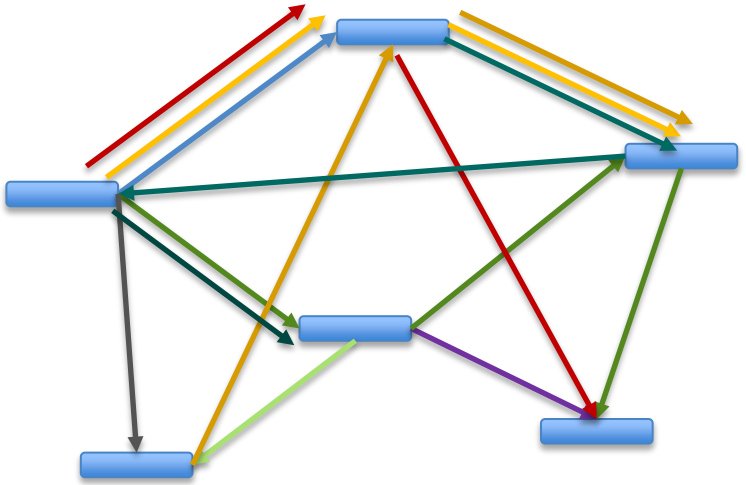
- Flight schedules
  - Not take-off to landing but gate-to-gate
  - Consider taxi times and buffers!

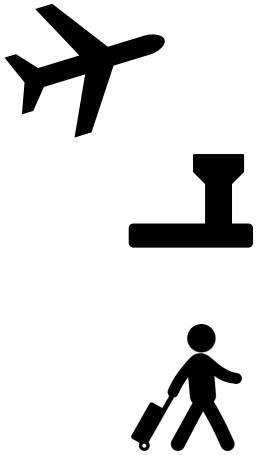


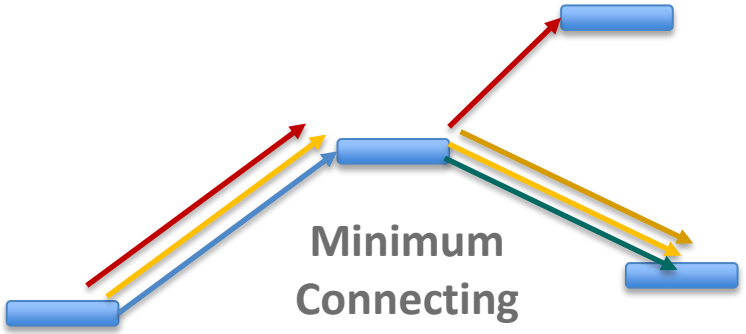
Modelling considerations

Transportation Research Laboratory

- What should be considered in ATM modelling?





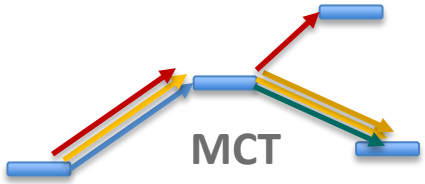


Minimum Connecting Time (MCT)

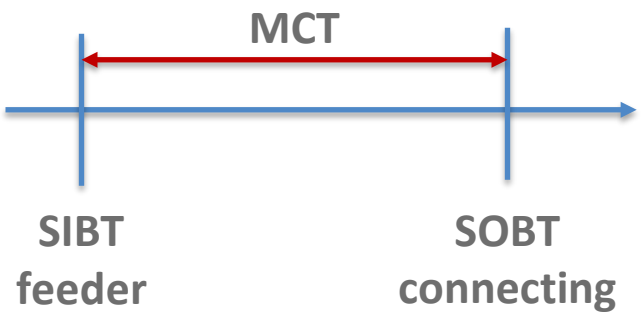
Modelling considerations

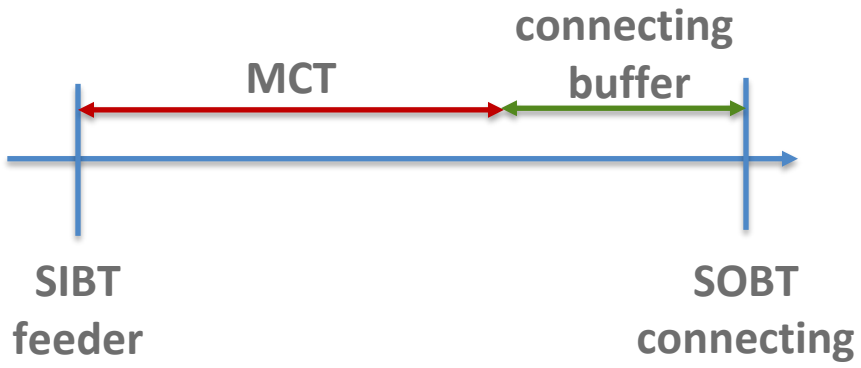
- What should be considered in ATM modelling?

- MCT depends on parameters such as
  - Airport (even terminal)
  - Type of connection (domestic, international)
  - Type of passenger
  - Airline
- MCT will define if a potential itinerary is possible



One day 2014 (ECAC)
~3.4 M pax
91.4% single leg
8.3% two legs (~280K pax)
0.3% three legs (~9K pax)





Modelling considerations

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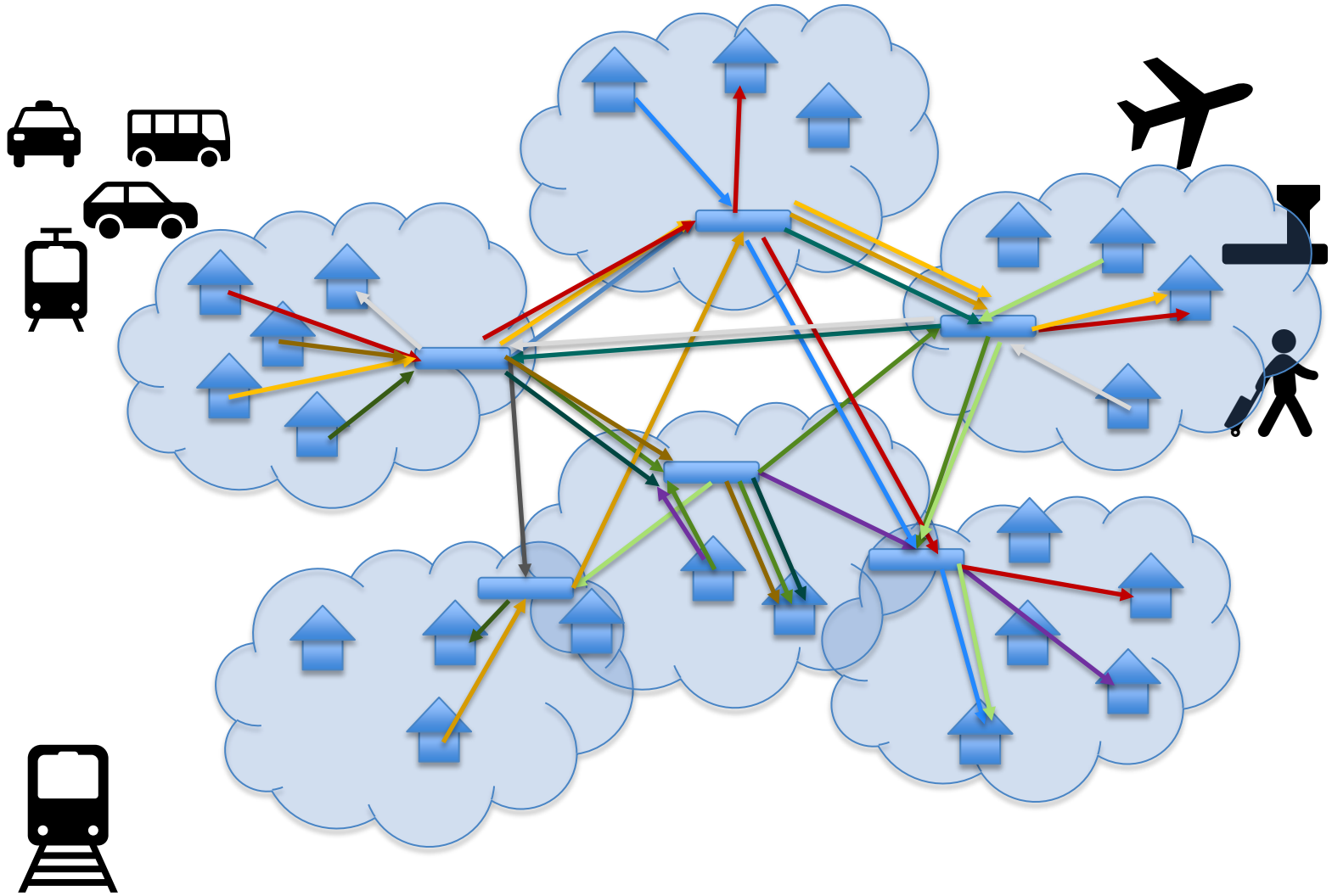

Modelling considerations

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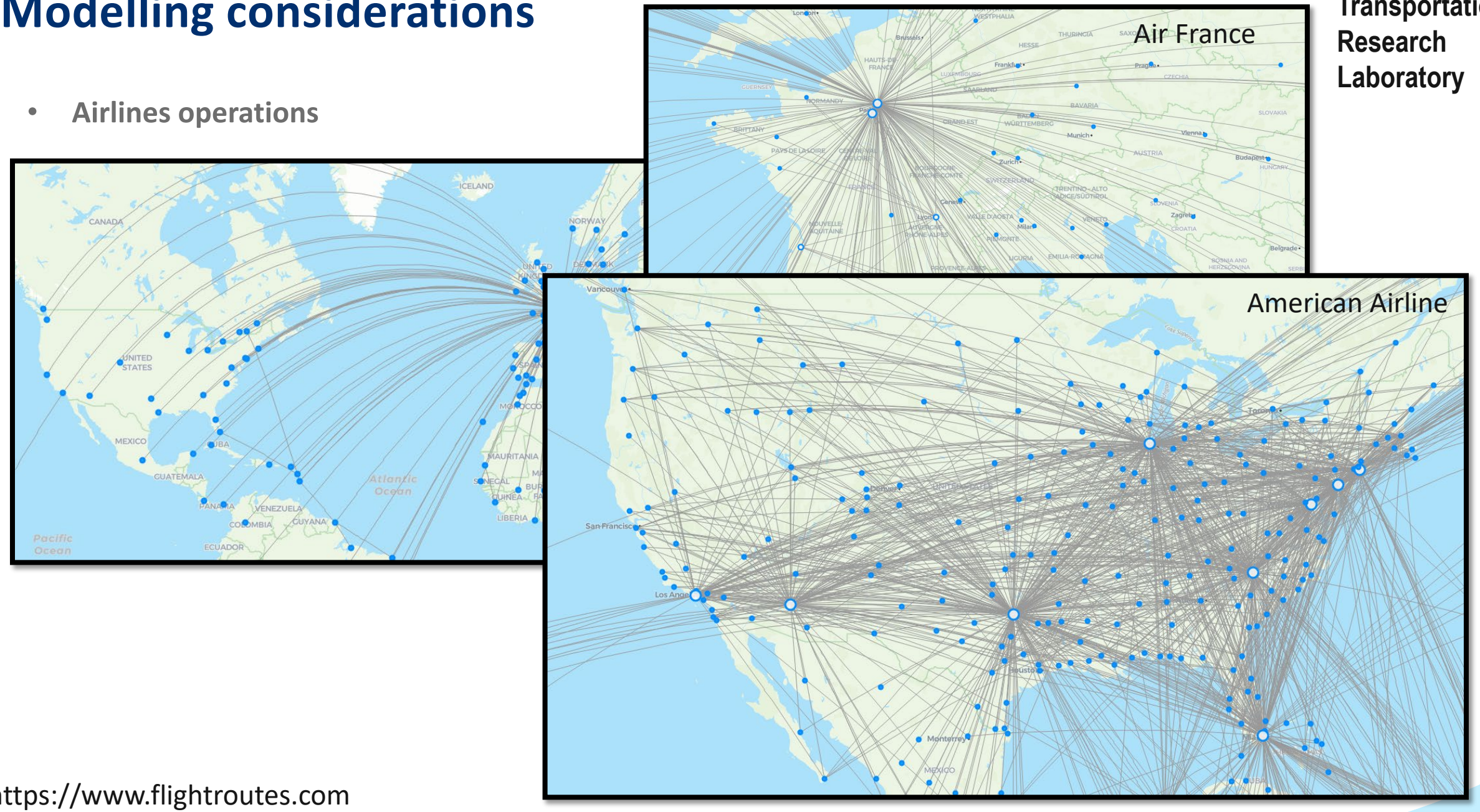
- Airlines operations



https://www.flightroutes.com

Modelling considerations

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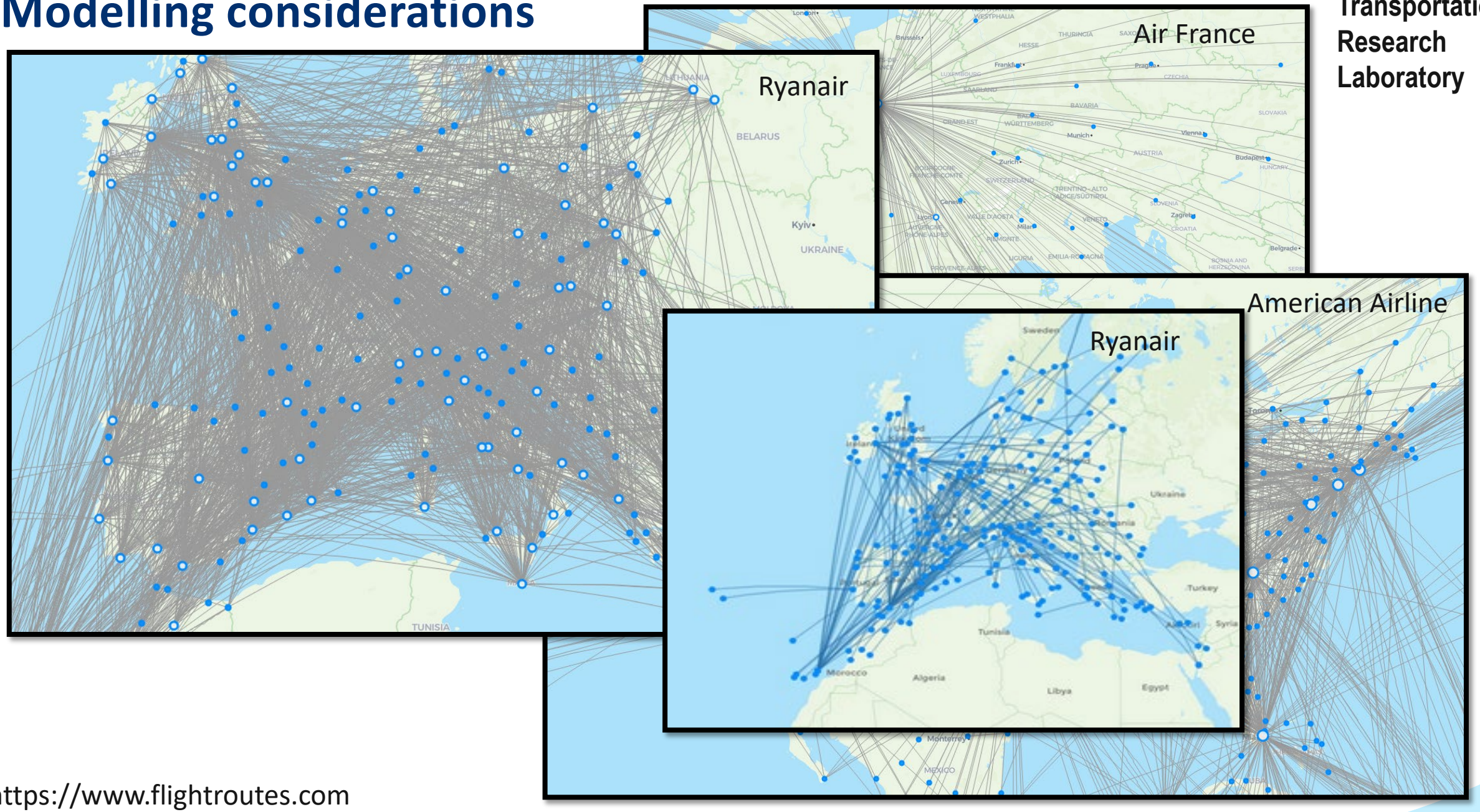

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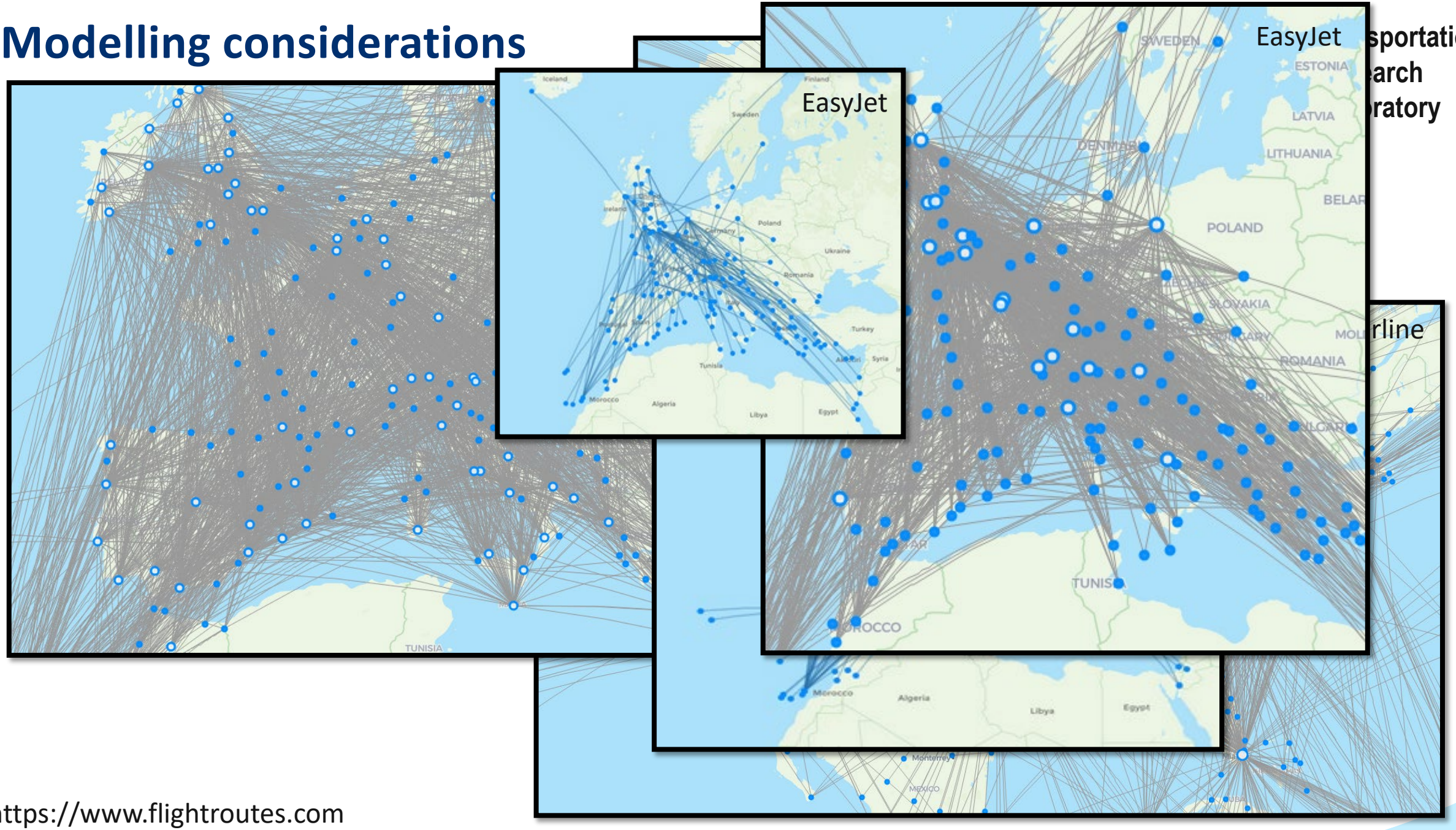
Modelling considerations



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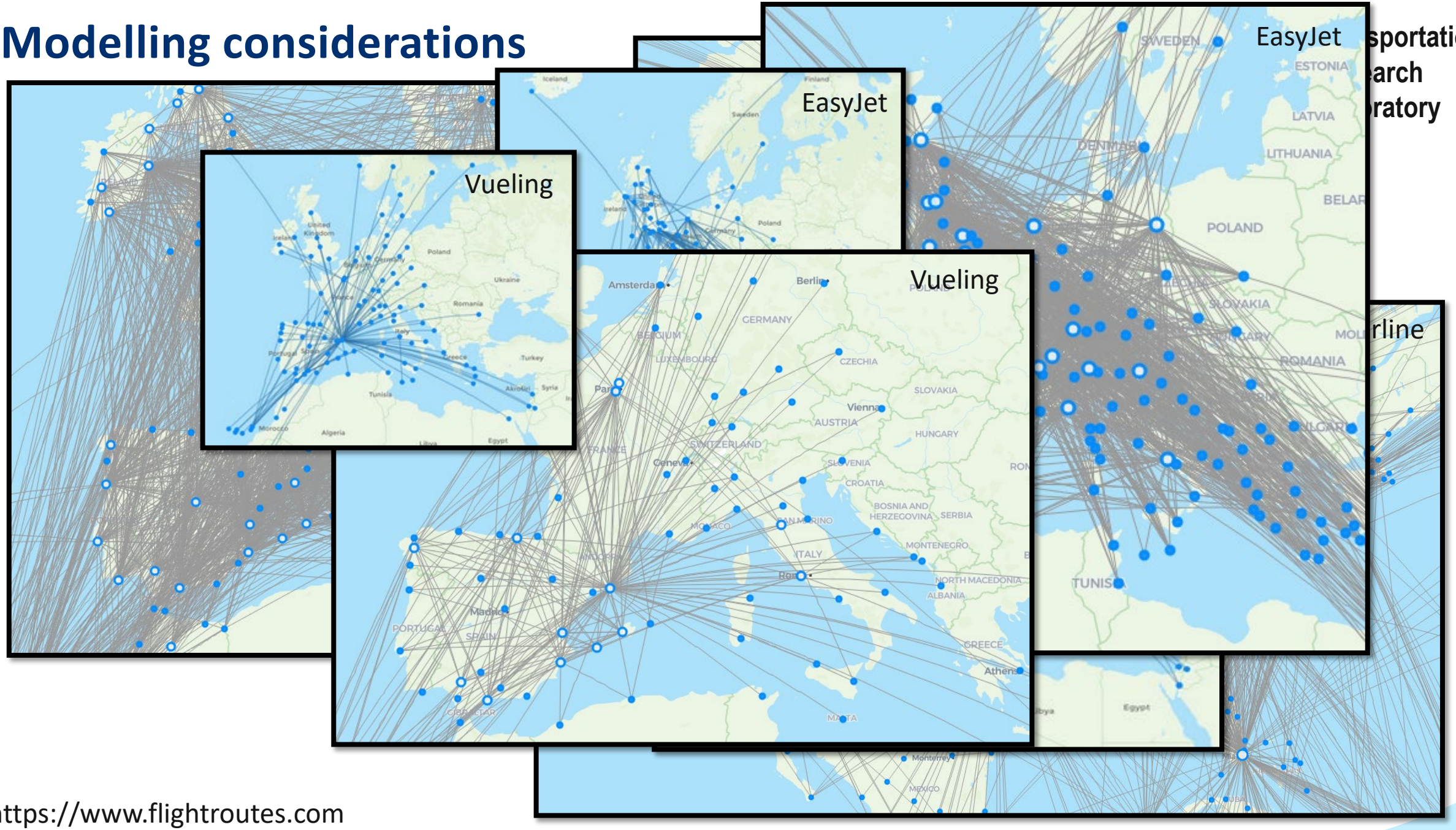

https://www.flightroutes.com

Summary on modelling considerations

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- Right level for right problem!
- Reactionary delay (~43% all delay (2019))
- Buffers
- Pax (and connections) can be important
- Cost modelling (cost of delay) (driver of behaviour and non-linear)

EUROCONTROL, 2020. CODA Digest All-causes delay and cancellations to air transport in Europe – Annual report for 2019
A. Cook and G. Tanner, “European airline delay cost reference values, updated and extended values,” University of Westminster, Tech. Rep., 2015, v4.1

Autum School 2025

Thank you!

Transportation Research Laboratory

Quintin Hogg Trust