CINQUIEME SEMESTRE
Spécialité Avionique et Systèmes de Contrôle du Trafic Aérien

SB508
Ground based Safety Nets

Nov 2016

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Outline

- Personal presentation
- Lesson 1 : Context
- Lesson 2 : Safety nets in general
- Lesson 3 : MSAW & APM
- Lesson 4 : APW + Conclusions
- Lesson 5 : STCA

Outline

- Personal presentation
- Lesson 1 : Context
- Lesson 2 : Safety nets in general
- Lesson 3 : MSAW & APM
- Lesson 4 : APW + Conclusions
- Lesson 5 : STCA

Outline of lesson3

- Chapter 1 : Basis of STCA
- Chapter 2 : Acquisition of data
- Chapter 3 : Filtering function in ACC
- Chapter 4 : Prediction function in ACC
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- Chapter 6 : Alert process in ACC
- Chapter 7 : Filtering function in APP
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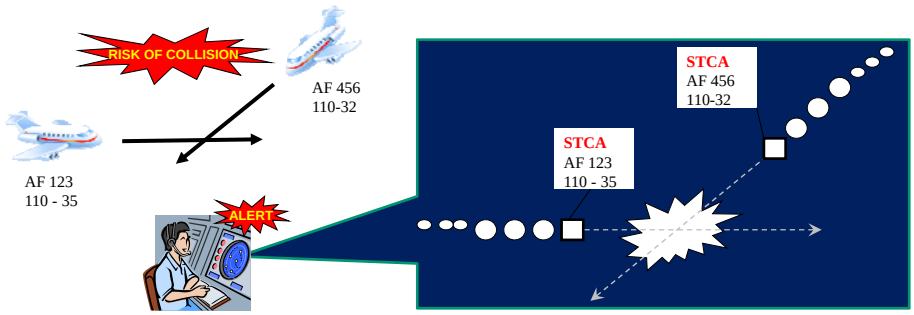
1.1 Basis : Introduction

- STCA is a ground safety net, which predicts the trajectory of planes and alert controller in case of risk of collision (predicted in the next 2 minutes) between 2 aircrafts .
- The 2 aircrafts in alert are displayed in the screen with a specific label



1.2 Basis : Common aspects ACC and APP

- We have seen that we have 2 kinds of STCA.
  - STCA for the Area Control Center (ACC)
  - STCA for the APProach center (APP).

1.3 Basis : What is a conflict between 2 planes ?

Two planes are in conflict when the horizontal and vertical separation will be under the normal separation during the Notice time.

1.4 Basis : Notice time

- The Notice time is the time needed for all the users and all the system to react and so to avoid the conflict.
- So to calculate the notice time , we must add all those following times :
  - controller reaction
  - controller instruction for the pilot
  - technical ground and air system to bring the information to pilot and controller
  - pilot reaction
  - plane reaction

1.5 Basis : What is a “normal” separation between 2 planes ?

in ACC :

- Horizontal separation is :
  - 5 Nm (=> 5Nm x 1,852m = 9,26 km)
- Vertical separation is :
  - FL 290 to FL 410 => 2000 ft or 1000ft in RVSM condition (Reduced Vertical Separation Minima)
  - FL 410 and above => 4000 ft

in APP :

- Horizontal separation is :
  - 2,5 or 3 Nm (=> 3Nm x 1,852m = 5,56 km)
- Vertical separation is : 1000 ft

1.6 Basis : RVSM

RVSM : Reduced Vertical Separation Minima

RVSM conditions require on board equipment conditions :

- 2 independent altitude measurement systems on board
- Altitude alerting system (alert if altitude decreasing 200ft/mn)
- Automatic altitude control system (in the automatic pilot, sustain altitude)
- Secondary surveillance radar transponder with altitude reporting system that can be connected to the altitude measurement system in use for altitude keeping

1.7 Basis : Too much false alerts detected

- What does it happen, if too much false alerts are present?
  - nuisance for the controller
  - the controller don't trust the system
  - the controller could ignore alerts
- We see that too much false alerts are not good for safety !!!

1.8 Basis : How does STCA works

- The STCA installed in the ACC is totally different from the STCA installed in the APP.
- This is why we will now present the 2 systems over different functions of SCTA.

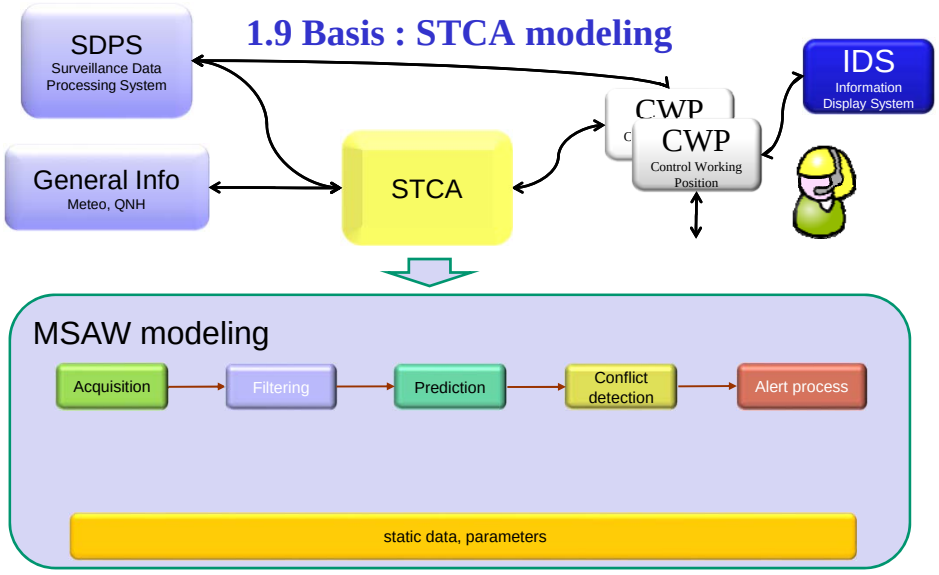
1.9 Basis : The French context

- The French national committee for safety, after different survey and analysis , see that some reasons of incidents in the approach control center could be due to the growing traffic.
- In 1992, this committee propose to install STCA in approach control center.
- This STCA (in the approach) must be adapted to the approach with his specificity.

1.10 Basis : In France since 1996

- In 1996, a project is started to install it in the approach.
- in 1996, first tests made in 2 Airports
  - Paris Orly
  - Paris Charles de Gaulle.
- Since 2001, all the major French approach center have installed STCA

1.9 Basis : STCA modeling



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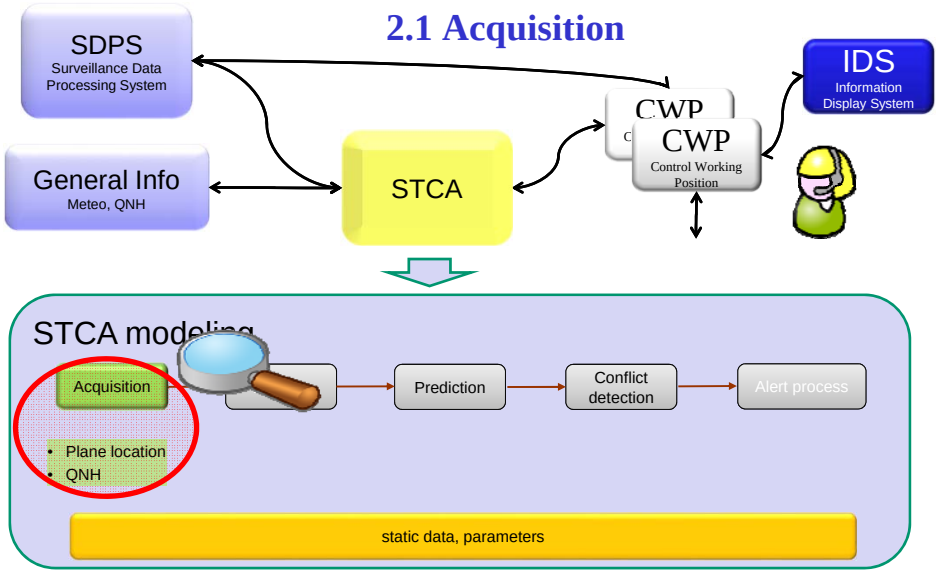
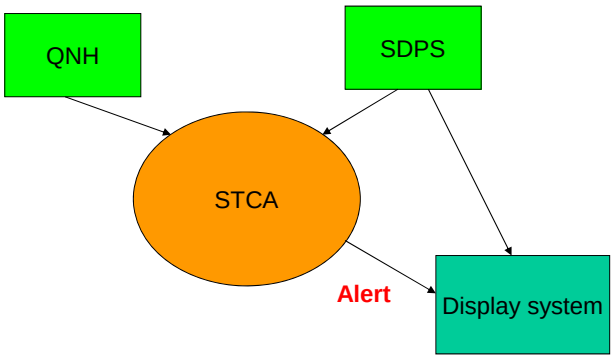
2.1 Acquisition



2.2 Acquisition : dynamic data

- STCA in ACC and in APP uses inputs data :
  - from a Radar Data Processing System (SDPS) :
    - Cinematic data vertical and horizontal speed (using the position, the vertical and the horizontal speed, the future position will be calculated)
    - Flight Level of plane
  - from meteo systems : QNH : Q code indicating the atmospheric pressure of airport adjusted to sea level.

2.3 Basis : Inputs & Outputs



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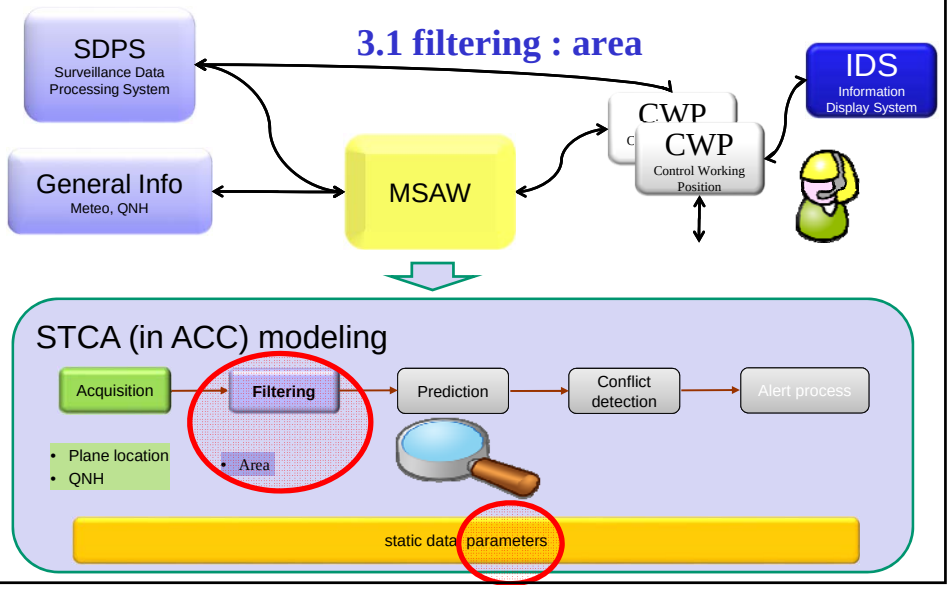
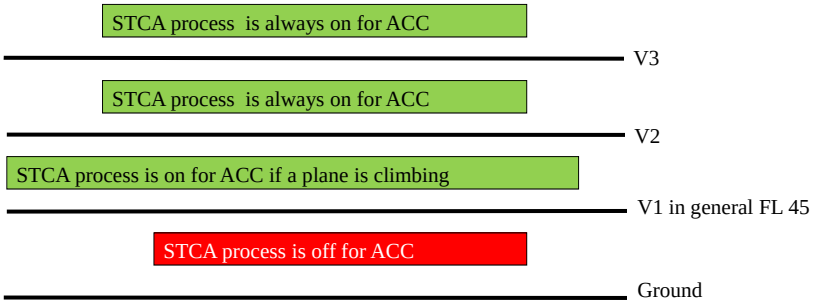
3.1 filtering : area



3.2 filtering : layers

- Process is inhibited
  - in lower layer (APP layers)
  - For VFR and military code
- The layers set up for STCA in ACC are :
  - below volume V1, STCA is inhibited
  - between volume V1 et volume V2, alerts are enabled if one of the aircrafts is climbing
  - volume V3 is at the end of terminal volume

3.3 filtering : layers



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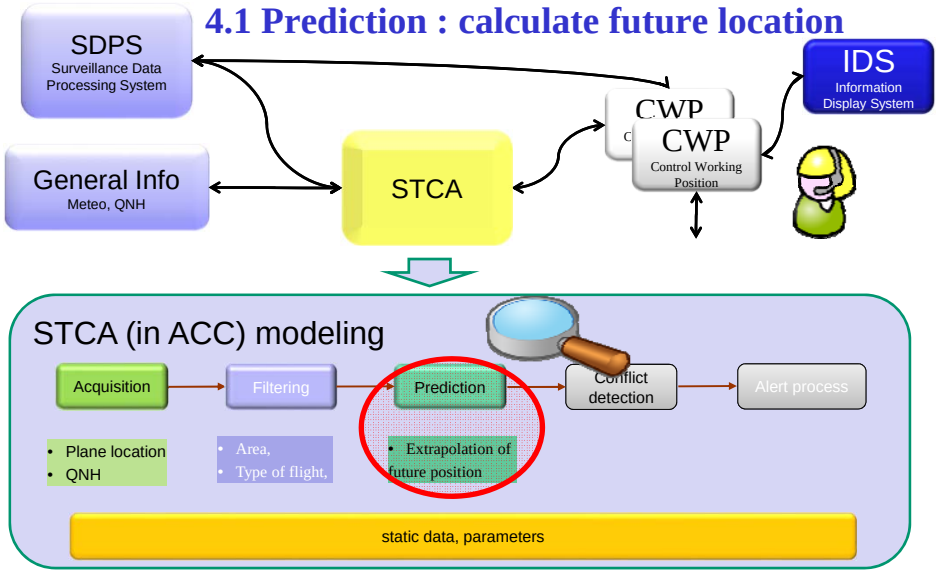
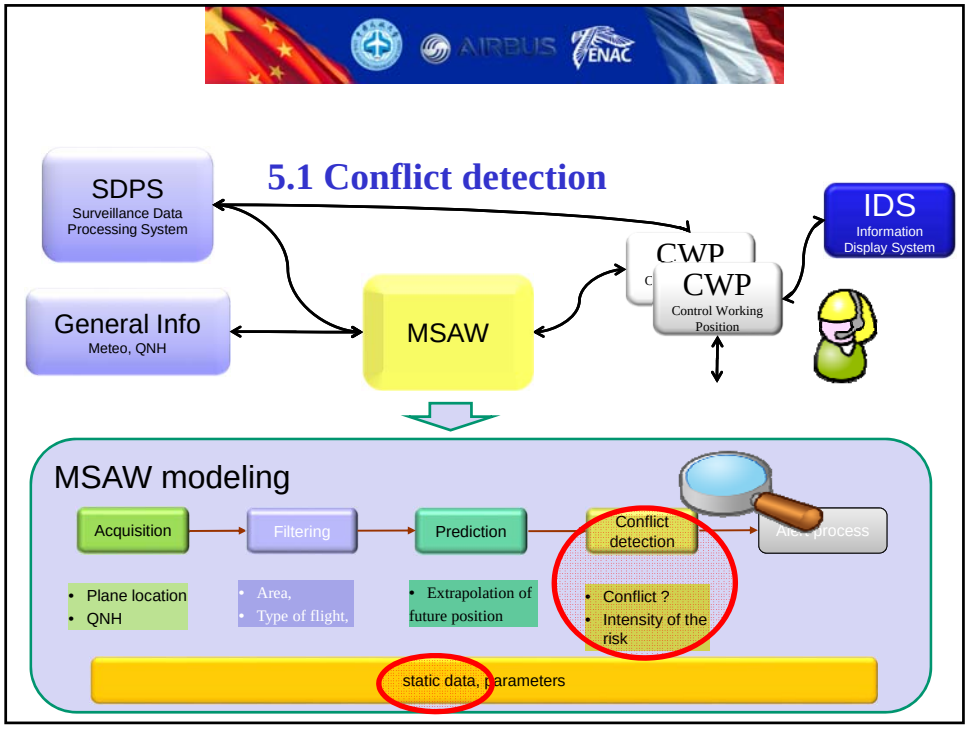
4.1 Prediction : calculate future location



4.2 Time prediction

- Notice time used by STCA system is about : 2 minutes

Outline of lesson3



5.2 Conflict detection : Remain what is a conflict between 2 planes

Two planes are in conflict when the horizontal or vertical separation will be under the normal separation during the Notice time.

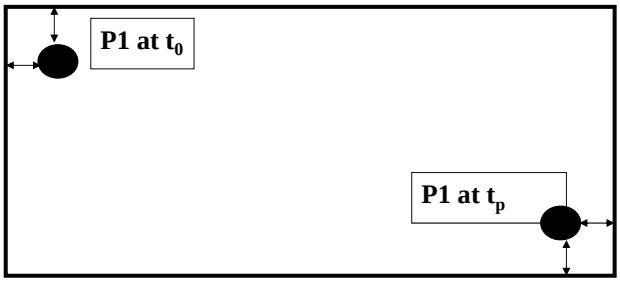
5.3 Conflict detection : remain “normal” separation between 2 planes in ACC

in ACC :

- Horizontal separation is :
  - 5 Nm (=> 5Nm x 1,852m = 9,26 km)
- Vertical separation is :
  - FL 290 to FL 410 => 2000 ft or 1000ft in RVSM condition (Reduced Vertical Separation Minima)
  - FL 410 and above => 4000 ft

5.4 Travel domain and conflict

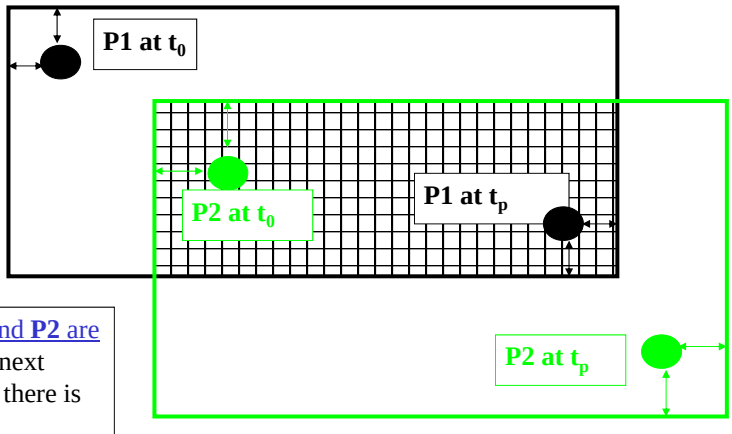
- Travel domain
  - For each aircraft, a travel domain is calculated. This domain is the area where we are sure that the aircraft will be between t0 and Prediction Time tp.



5.5 Conflict or not

- Conflict :
  - if an overlap domain is detected between 2 travel domain , a conflict is monitored, then displayed to the controller
- No conflict
  - If no overlap detected between 2 travel domain for an even of tracks , this even is rejected for the conflict process.

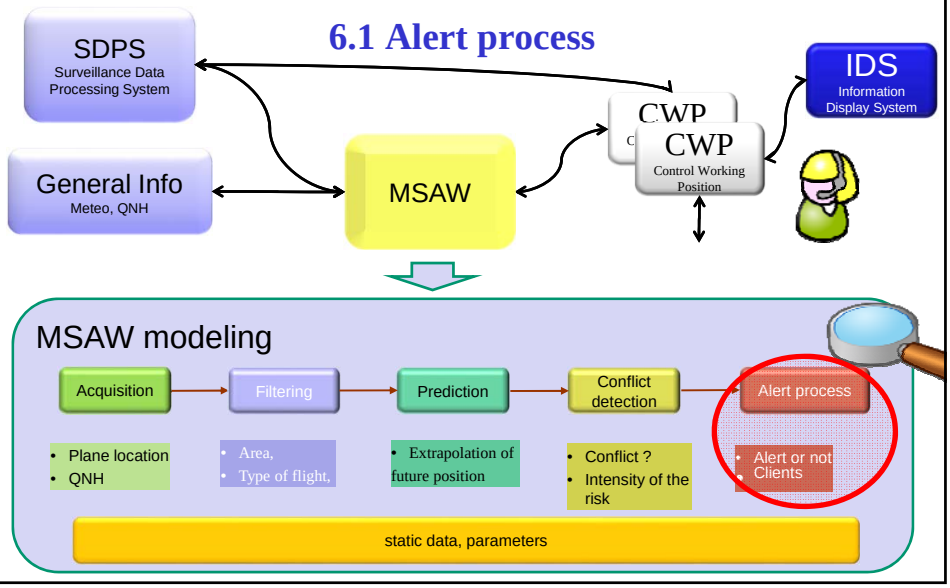
5.6 Conflict or not



The planes **P1** and **P2** are **selected** for the next process because there is an overlap.

Outline of lesson3

6.1 Alert process



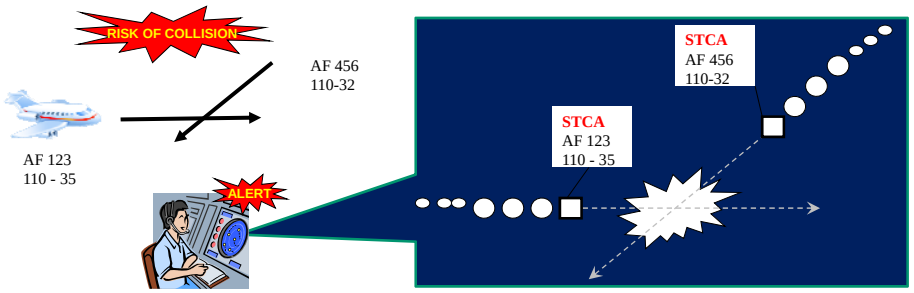
6.2 Alert process : display alert in ACC

- In the ACC, to display the alert, we must have :
  - transponder code are not military code or VFR codes
  - simultaneous conflict in horizontal and vertical plans
  - conflict time upper to 10 s
  - end of conflict predict time 10s after now

6.3 Alert process : Set up for STCA in ACC

- Let's take the case of an ACC over an APP.
  - In case of conflict in airspace inside ACC sectors, the 2 planes with the alert are displayed in the ACC sectors
  - If one of the plane will go to the approach, the 2 planes in conflict will be also displayed in ACC

6.4 Alert process : Outputs : Displaying the STCA alert



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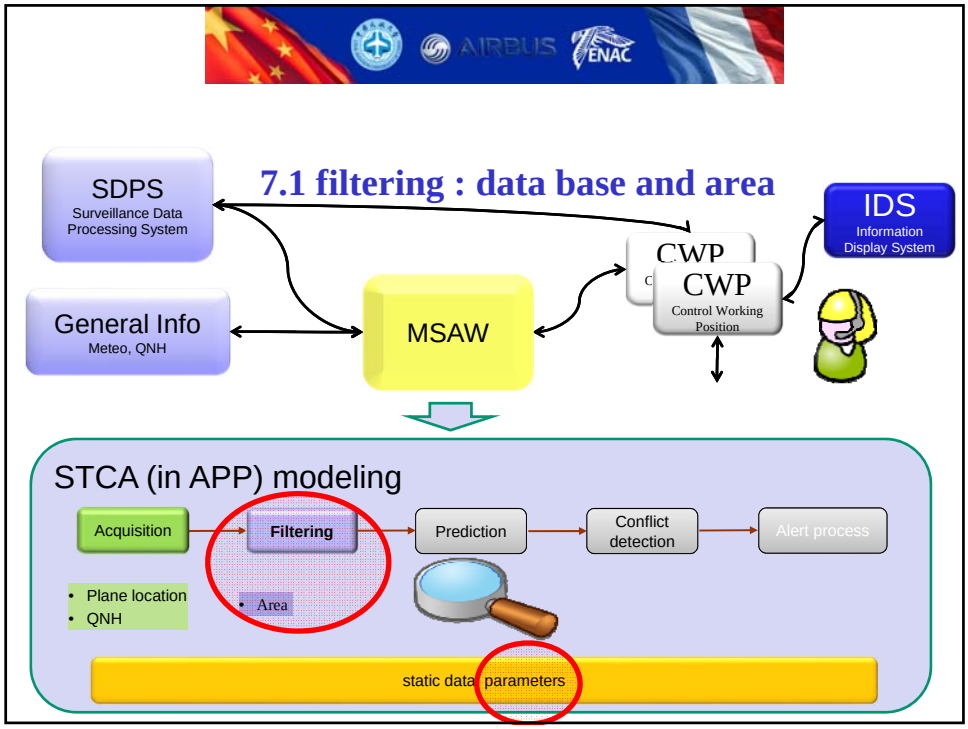
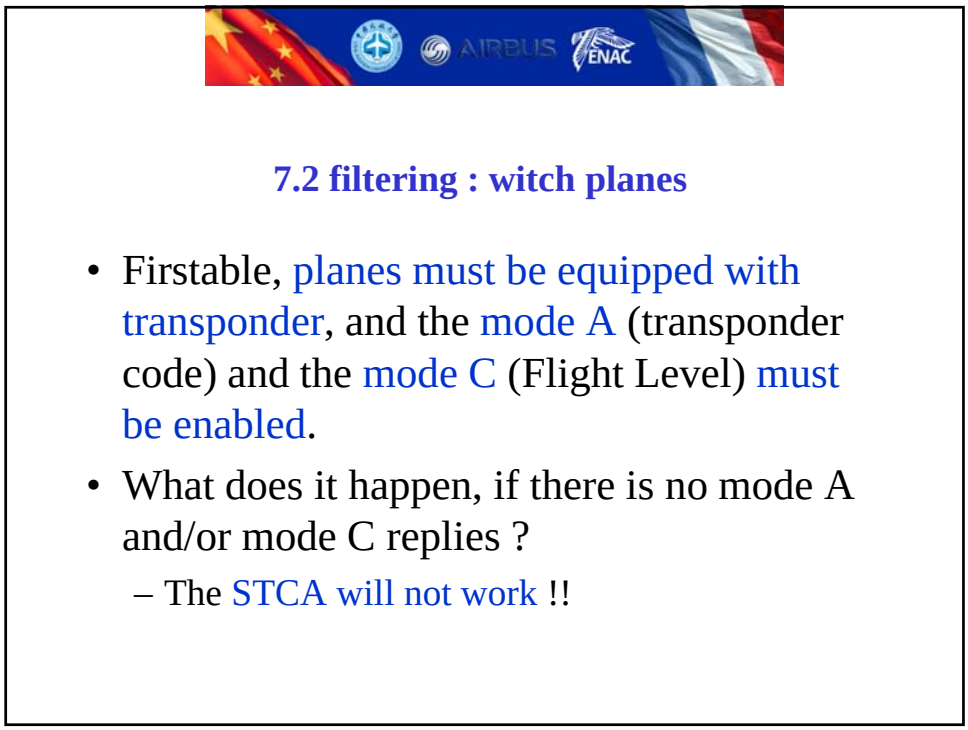




7.2 filtering : witch planes

- Firstable, planes must be equipped with transponder, and the mode A (transponder code) and the mode C (Flight Level) must be enabled.
- What does it happen, if there is no mode A and/or mode C replies ?
  - The STCA will not work !!

7.3 Filtering

- This process uses 2 sub process.
  - eligibility
  - mosaic filtering

- *Eligibility*
  - A track (= a plane) is selected if Flight Level and speed are present in a template
- *Mosaic filtering:*
  - Eliminate some even aircraft which are to far. At the end, a list of even aircrafts for the SCTA processing is made

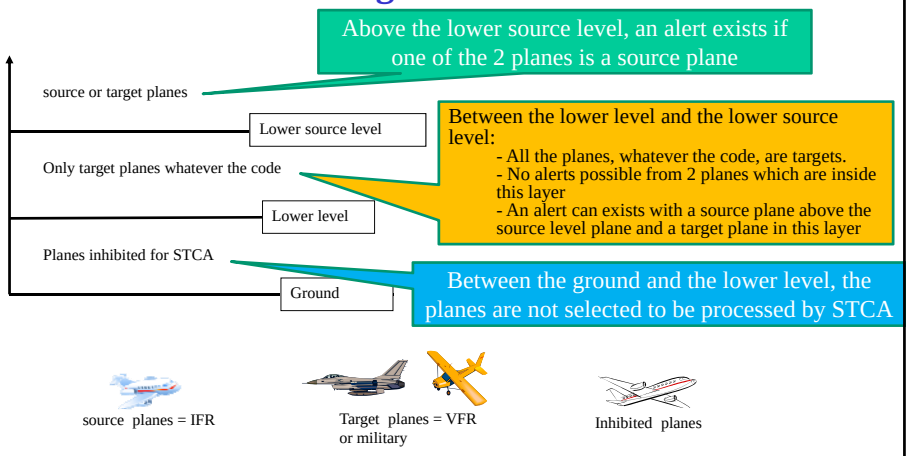
7.4 Filtering : witch Areas ?

- Vertical Area
- Approach area
- Processing area
- Inhibition areas

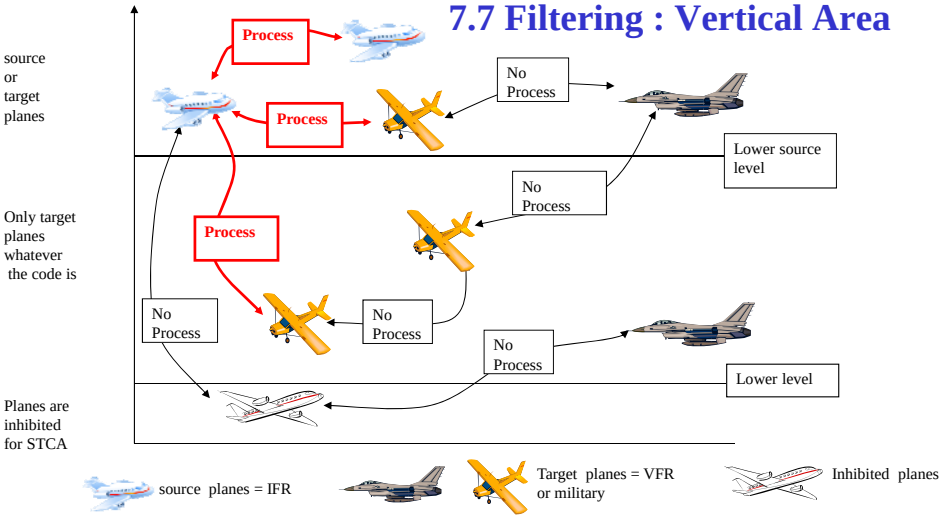
7.5 Filtering : Vertical Area

- In each approach , a specific set up called “Domain of interest” must be created to define different vertical levels.
- There are 3 levels:
  - from ground to “lower level”
    - in this layer the planes are inhibited
  - from “lower level” to “lower source level”
    - in this layer there is only target plane whatever the mode A (code)
  - Above the “lower source level”
    - In this layer , there is source or taget plane depending on mode A (code)

7.6 Filtering : Vertical Area



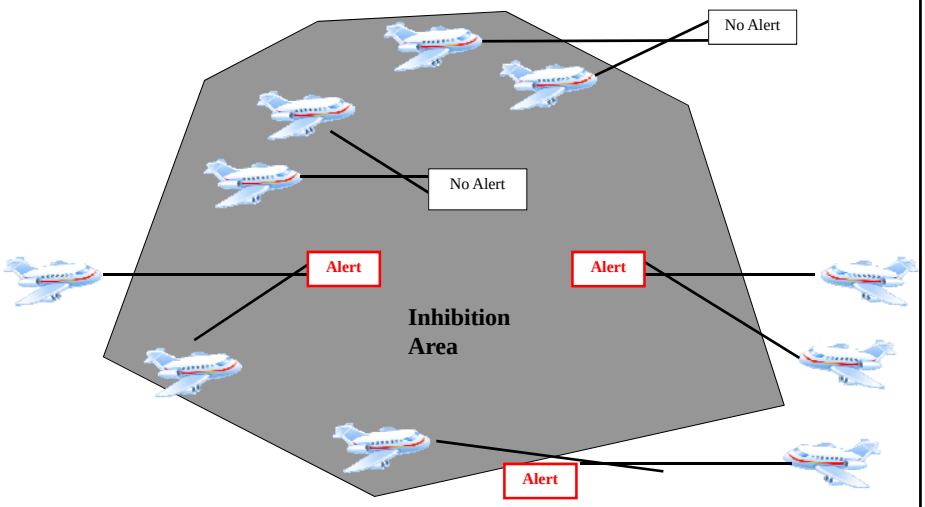
7.7 Filtering : Vertical Area



7.8 Filtering : Inhibition area

- inhibition area above the “lower source level” can be created
- The SCTA process is not considered if the 2 planes are inside the inhibition area. We can see some examples in the next diagram.

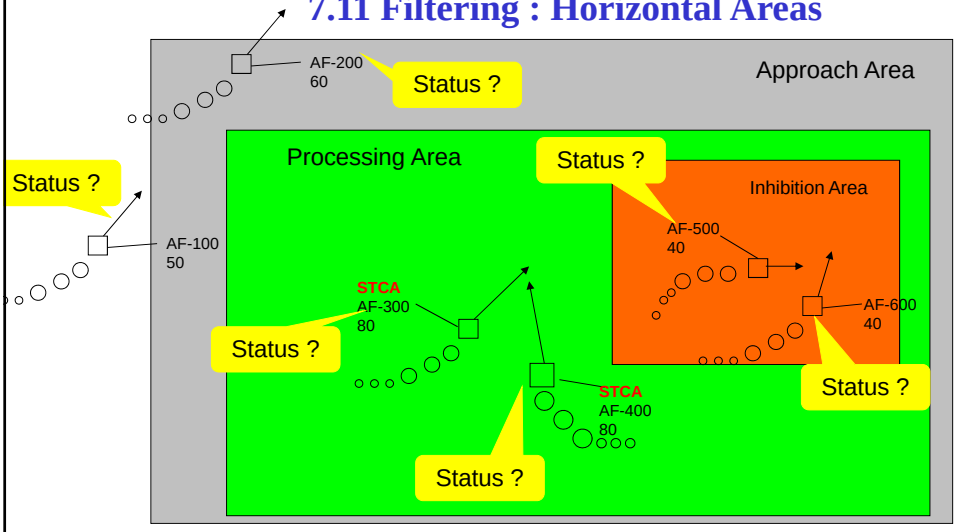
7.9 Filtering : Inhibition area



7.10 Filtering : Horizontal Areas

- Horizontal Area
  - Approach area
  - Processing area
  - Inhibition areas

7.11 Filtering : Horizontal Areas



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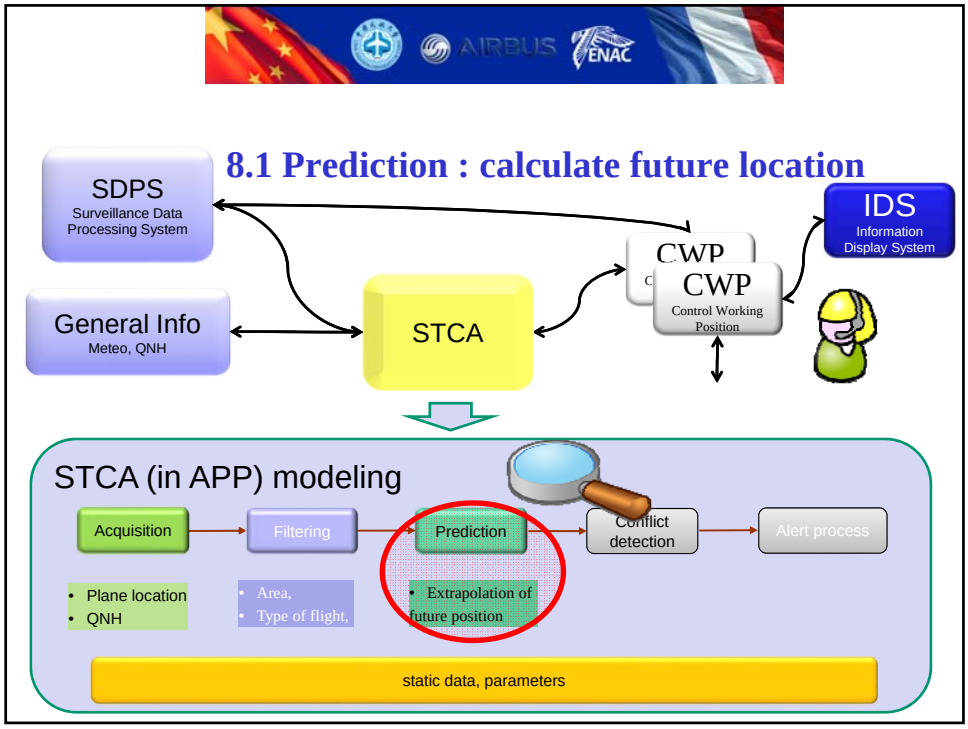
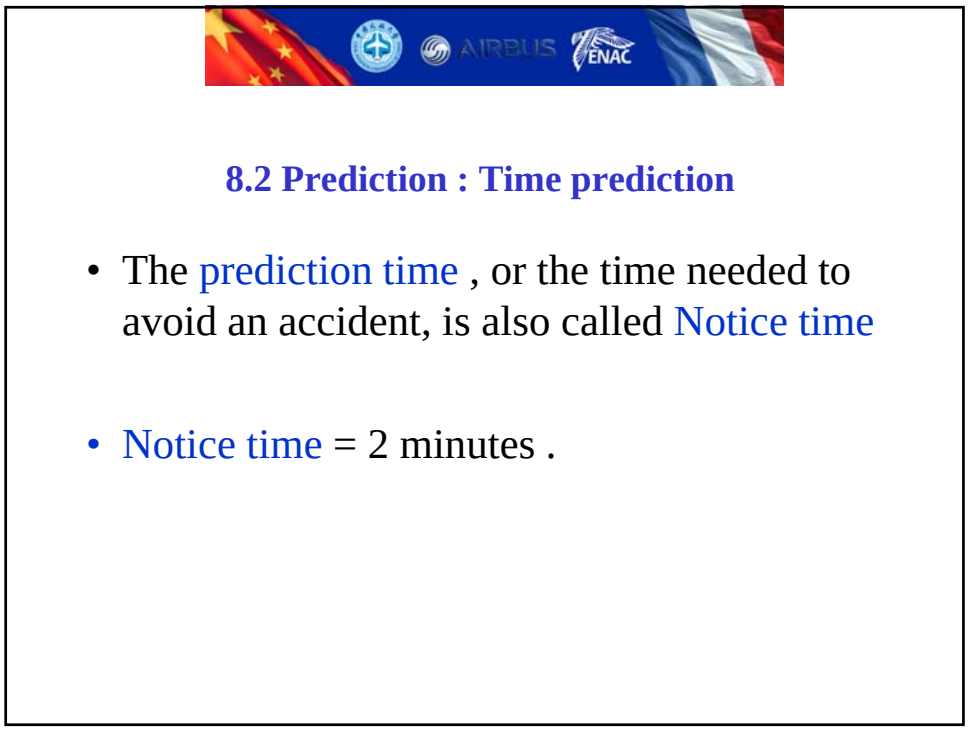




8.2 Prediction : Time prediction

- The prediction time , or the time needed to avoid an accident, is also called Notice time
- Notice time = 2 minutes .

8.3 Prediction : in vertical and horizontal

- DOI = Domain of Interest (area where STCA will work)
- Predictions
- It's possible for a flight to predict :
  - in vertical intention (climbing or descending)
  - in a horizontal intention (turning right or left, continuing straight away).

8.4 Prediction : large filtering

- This prediction process uses 2 sub process :
  - Large "filtering" in horizontal
  - large "filtering" in altitude

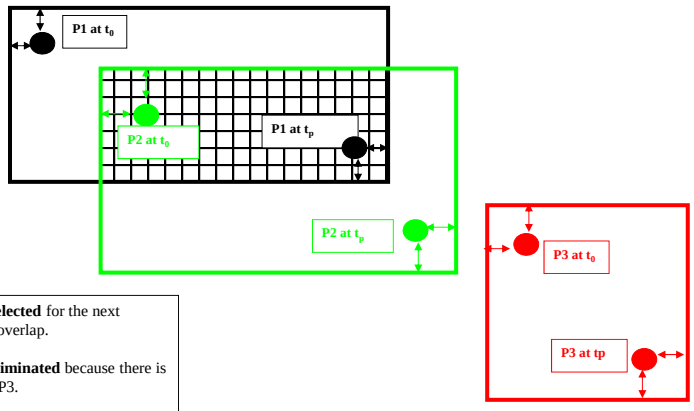
8.5 Prediction : Large filtering in horizontal

- For each even track, the future position is calculated until the prediction time.
- A square is made for each plane (actual position, predict position). If an overlap is present, even tracks are kept.
- Let's take an example with 3 Planes (P1,P2 and P3).

8.6 Prediction : Large filtering in horizontal

- For each plane we have :
  - For the actual position
    - The position at time actual time = t0
    - Horizontal margin at actual position
  - For the predicted position
    - the position at predicted time = tp
    - Horizontal margin at predicted position
- A square made by the 2 previous points.
- Let's see it , in the next slide …

8.7 Prediction : Large filtering in horizontal



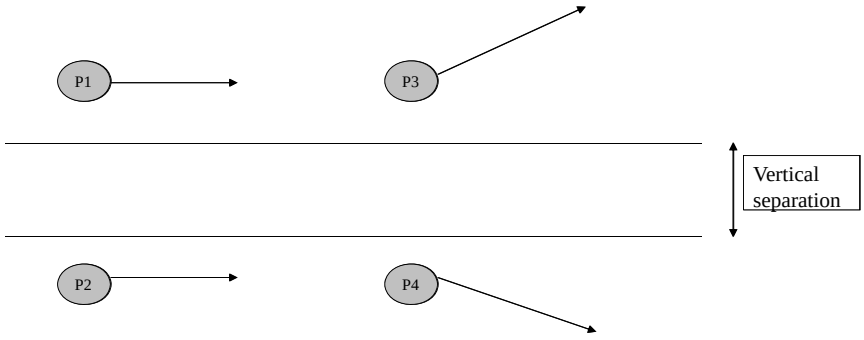
The planes **P1** and **P2** are **selected** for the next process because there is an overlap.

The planes **P1** and **P3** are **eliminated** because there is no overlap between P1 and P3.

The planes **P2** and **P3** are eliminated because there is no overlap between P2 and P3.

8.8 Prediction : Large filtering in altitude

- Planes are eliminated for next process if :
  - they are in the vertical separation or more.
  - The vertical distance increase



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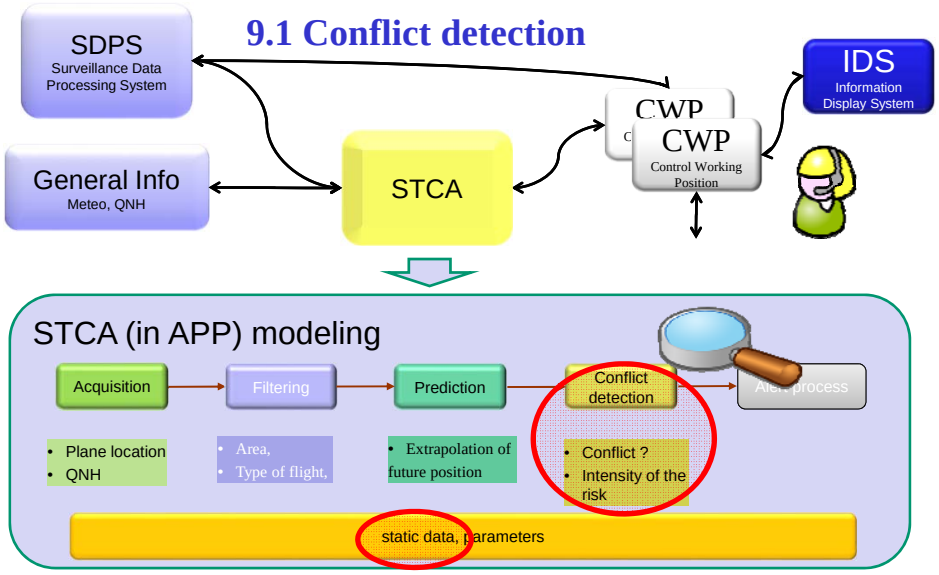
9.1 Conflict detection



9.2 Conflict detection : All the processes in STCA

- The detection of a conflict between 2 aircrafts is calculated each 4 seconds.
- For each even aircrafts, in the 2 next minutes, using :
  - the position,
  - the speed,
  - the direction
  - the standard separation

the system detect or not an infringement (violation) in separation.

9.3 Conflict detection : Separation in APP

- The separation in approach is :
  - 3 Nm in horizontal (up to 8 Nm , considering the surveillance system (radars))
  - 1000 ft in vertical
- If the horizontal and the vertical separation is under those values, a conflict is detected for 2 planes.
- A compromise must be found for the Notice time and the false alert rate.
- if an alert appears too soon, perhaps this alert is not real.

9.4 Conflict detection : Thin filtering

- This step will decide if the 2 tracks are in conflict. How to choose ?
- The 2 tracks are in conflict if the conflict is present in vertical and horizontal .
- So a horizontal thin filtering and a vertical thin filtering is calculated
- *In the Horizontal thin filtering :*
  - The horizontal distance and the horizontal Time conflict are calculated
- *Vertical thin filtering:*
  - The vertical distance and the vertical Time conflict are calculated
- All those calculations are made by extrapolations

9.5 Conflict detection : 4th process: Conflict detection

- In this process, 2 sub-process calculate:
  - the Conflict time and choose the hypothesis (HU, HM2, HM3, HM4 or HM5)
  - the quality of conflict and the beginning of conflict

9.6 Conflict detection : Multi-hypothesis processing

- Prediction are called HM :
  - Hypothese Multiple (in french) translated by Multi-hypothesis.
- An alert is displayed if one of the hypothesis predicts a conflict
- On the next table, we can see all the multi-hypothesis present in the STCA.

9.6 Conflict detection : Multi-hypothesis processing

Intention : No intention / Vertical intention Horizontal intention	**Name**	**Hypothese**	**Description**
No intention	HU	Hypothese Unique	No intention (Straight away)
Vertical Intention	HM2	Hypothese Multi n° 2	Vertical Intention (Climbing or descending)
Vertical Intention	HM3	Hypothese Multi n° 3	Vertical intention (Climbing or descending) and Stabilization
Horizontal Intention	HM4	Hypothese Multi n° 4	Horizontal Intention (turn right or left)
Vertical And Horizontal Intention	HM5	Hypothese Multi n° 5	Vertical Intention (Climbing or descending) AND Horizontal intention (turn right or left)

9.7 Conflict detection : Multi-processing in vertical

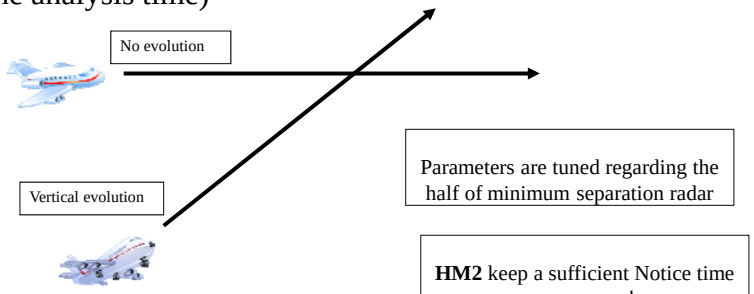
- **HM2** and **HM3** are calculated.
- In vertical , those process are used to eliminate some alerts for example HM3 is used when a flight take off (climbing) and stabilized his level during some minutes to avoids arrivals.
- The stabilized level after climbing is calculated using the speed and the proximity to a stabilized flight level.

9.8 Conflict detection : Multi-processing in vertical

- **HM2** : the flight continues his vertical evolution (during the analysis time)
- **HM3** : the flight stabilize in level (during the analysis time)

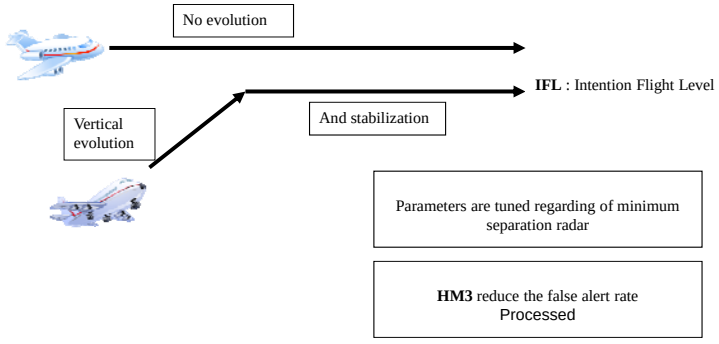
9.9 Conflict detection : Description of HM2

- **HM2** : the flight continues his vertical evolution (during the analysis time)

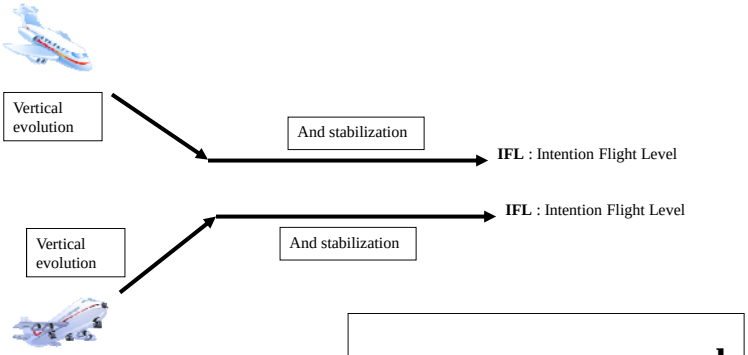


9.10 Conflict detection : Description of HM3

- **HM3** : the flight stabilize in level

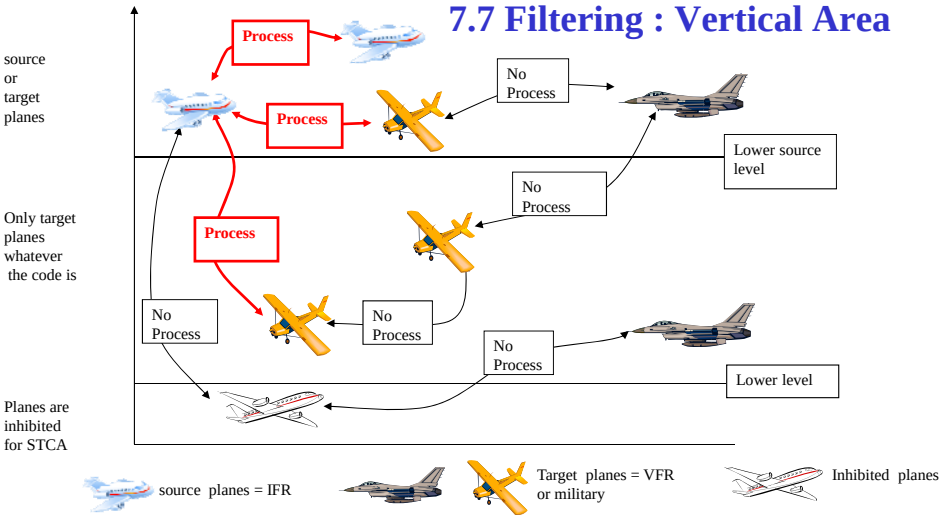


9.11 Conflict detection : Other cases HM2 , HM3

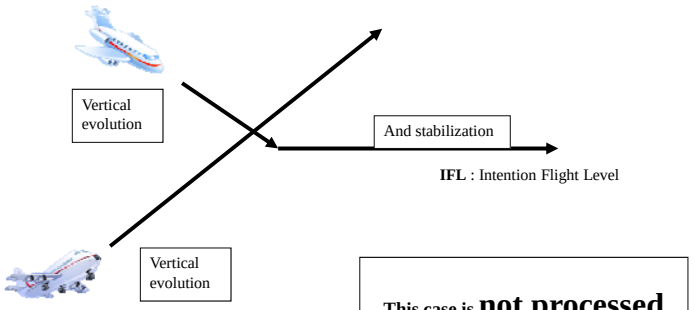


It's **HM3** . **This case is processed**

7.7 Filtering : Vertical Area

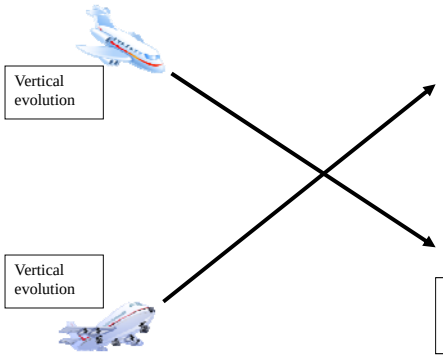


9.12 Conflict detection : Other cases HM2 , HM3



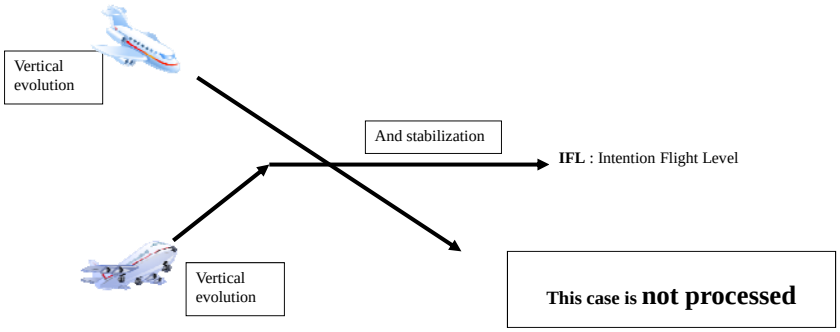
This case is **not processed**

9.13 Conflict detection : Other cases HM2 , HM3

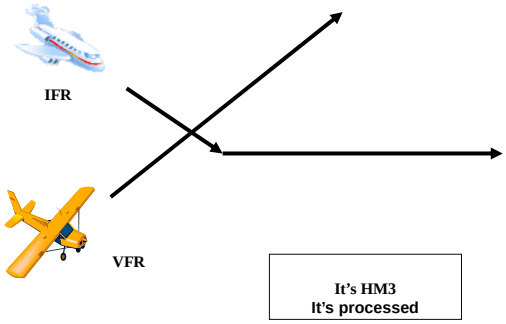


It's **HM2. This case is processed**

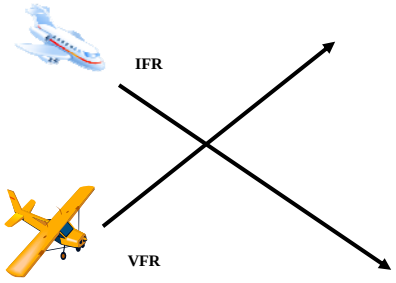
9.14 Conflict detection : Other cases HM2 , HM3



9.15 Conflict detection : HM2, HM3 with VFR and IFR



9.16 Conflict detection : HM2, HM3 with VFR and IFR



It's HM2

9.17 Conflict detection : Vertical intention in STCA

- The vertical intentions HM2, HM3 are very useful in the process for STCA in the APP context because there is a lot of :
  - departure (climbing) movements
  - arrival (descending) movements.

9.18 Conflict detection : Horizontal Hypothesis

- As we have vertical hypothesis, in STCA we have also Horizontal Hypothesis that are called HM4 and HM5

9.19 Conflict detection : Multi-hypothesis in horizontal

- For example, we can create near the airport, a turning area where we know that planes on a specific level will turn to land
- In this case **HM4** and **HM5** will be calculated.

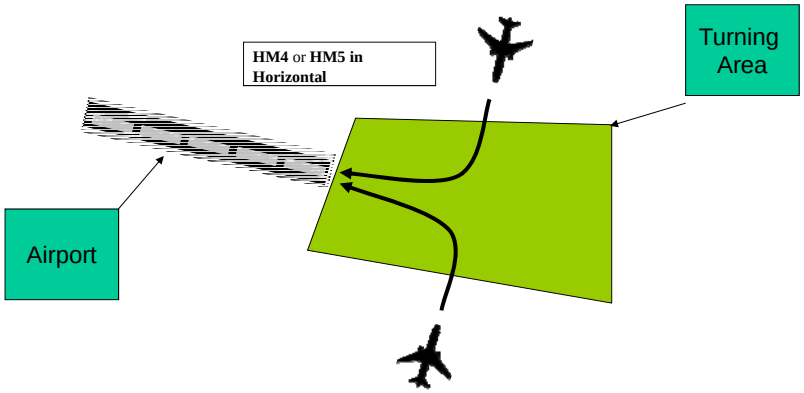
9.20 Conflict detection : Multi-processing in horizontal

- In horizontal, the processes are done to avoid some undesired alert.
- For example : in the case of 2 planes near the airport, we can create a **"turn area".**

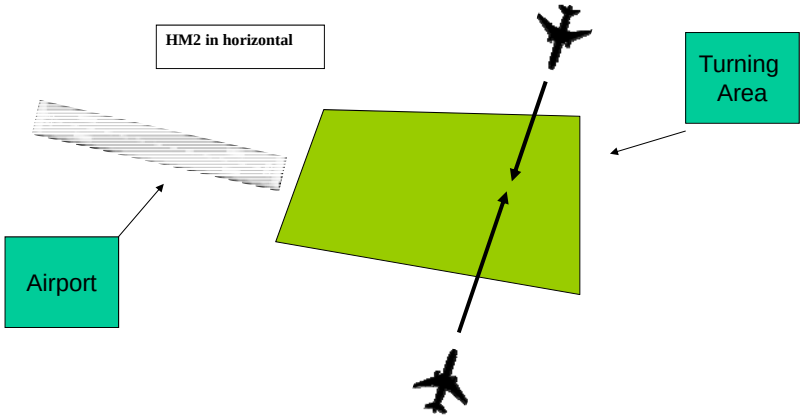
9.21 Conflict detection : HM4 or HM5 in horizontal

- STCA can calculate predictions using 2 hypothesis in this turn area :
  - the plane will turn and join the airport during analysis time. It's **HM4** or **HM5**
  - the plane will continue straight away during analysis time. It's **HM2**

9.22 Conflict detection : HM4 or HM5 in horizontal



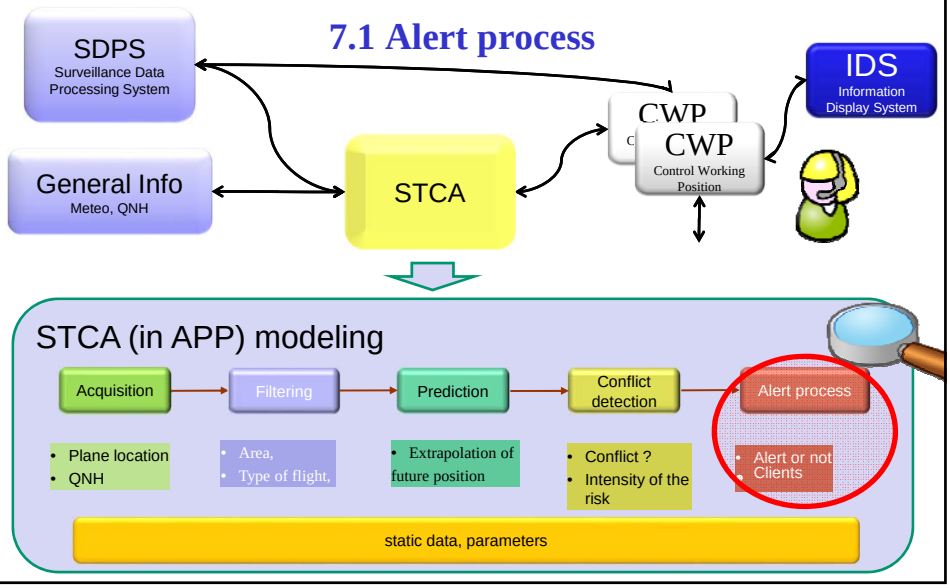
9.23 Conflict detection : HM2 in horizontal



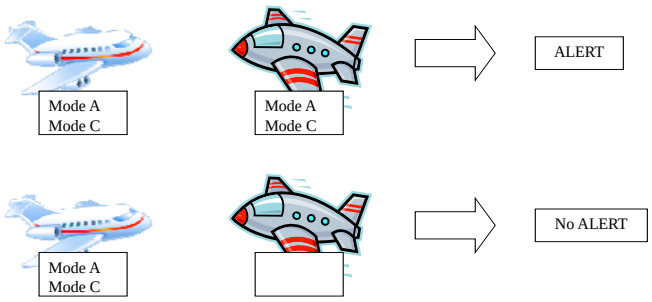
Outline of lesson3

- Chapter 1 : Basis of STCA
- Chapter 2 : Acquisition of data
- Chapter 3 : Filtering function in ACC
- Chapter 4 : Prediction function in ACC
- Chapter 5 : Conflict detection in ACC
- Chapter 6 : Alert process in ACC
- Chapter 7 : Filtering function in APP
- Chapter 8 : Prediction function in APP
- Chapter 9 : Conflict detection in APP
- Chapter 10 : Alert process in APP
- Chapter 11 : Conclusion

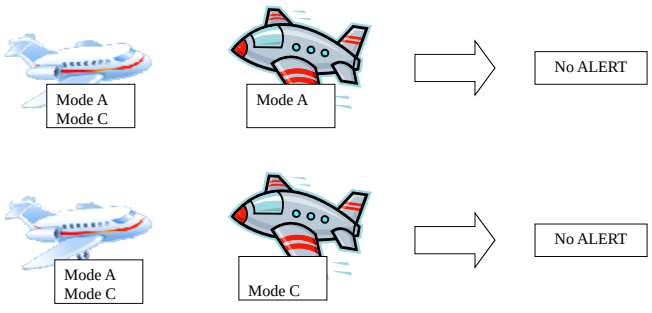
7.1 Alert process



7.2 Alert process : type of flights



7.3 Alert process : type of flights



7.4 Alert process : Source and target plane

- The software separate 2 kind of planes :
  - the source planes = IFR

source planes = IFR

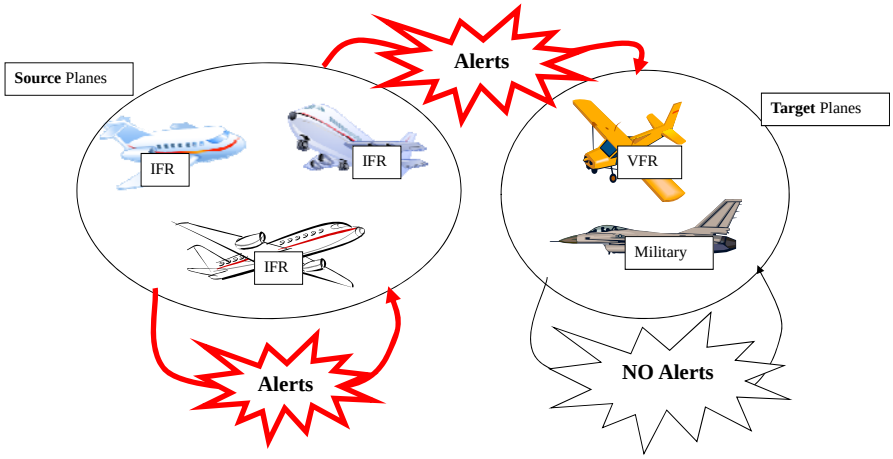
  - the target planes = VFR or Military

Target planes = VFR or military

7.5 Alert process : Alerts

- STCA detects conflict only between
  - source planes
  - source planes against target plane.
- No conflict detected between 2 targets
- Each approach have to describe the list of source and target planes.

7.5 Alert process : Alerts



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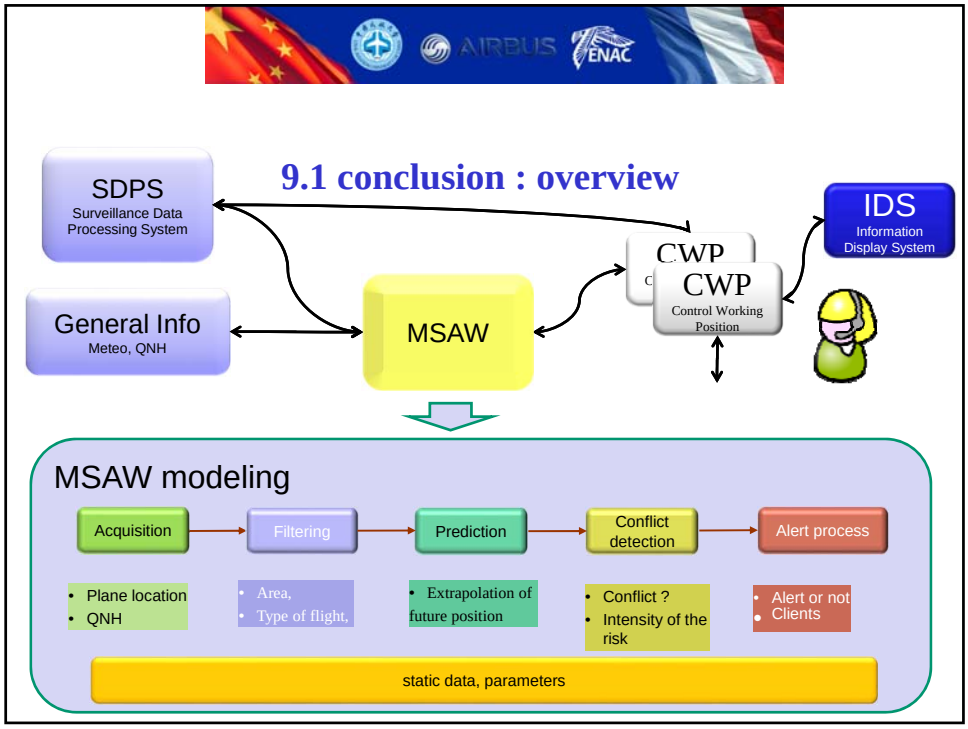

9,2 Conclusions : STCA versus TCAS

- To finish the presentation of STCA, we will talk about the airborne safety net : TCAS.
- The Notice time for STCA must be adequate to have a good global reaction : controller, pilot, plane .
- This Notice time must also be sufficient compare to TCAS.

9.3 Conclusions : STCA versus TCAS

- Indeed, STCA and TCAS are safety nets and work to avoid collision. They don't have the same role.
- The reaction loop for TCAS is shorter than STCA. And for TCAS an action is proposed (only in vertical plan).
- Controller have to separate the traffic without danger , so the STCA alert must arrived before the RA (Resolution Advisory) of the TCAS.

9.4 Conclusions : STCA versus TCAS