



4D contract concept overview

ONERA

THE FRENCH AEROSPACE LAB



THALES



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4D trajectory vs 4D contract

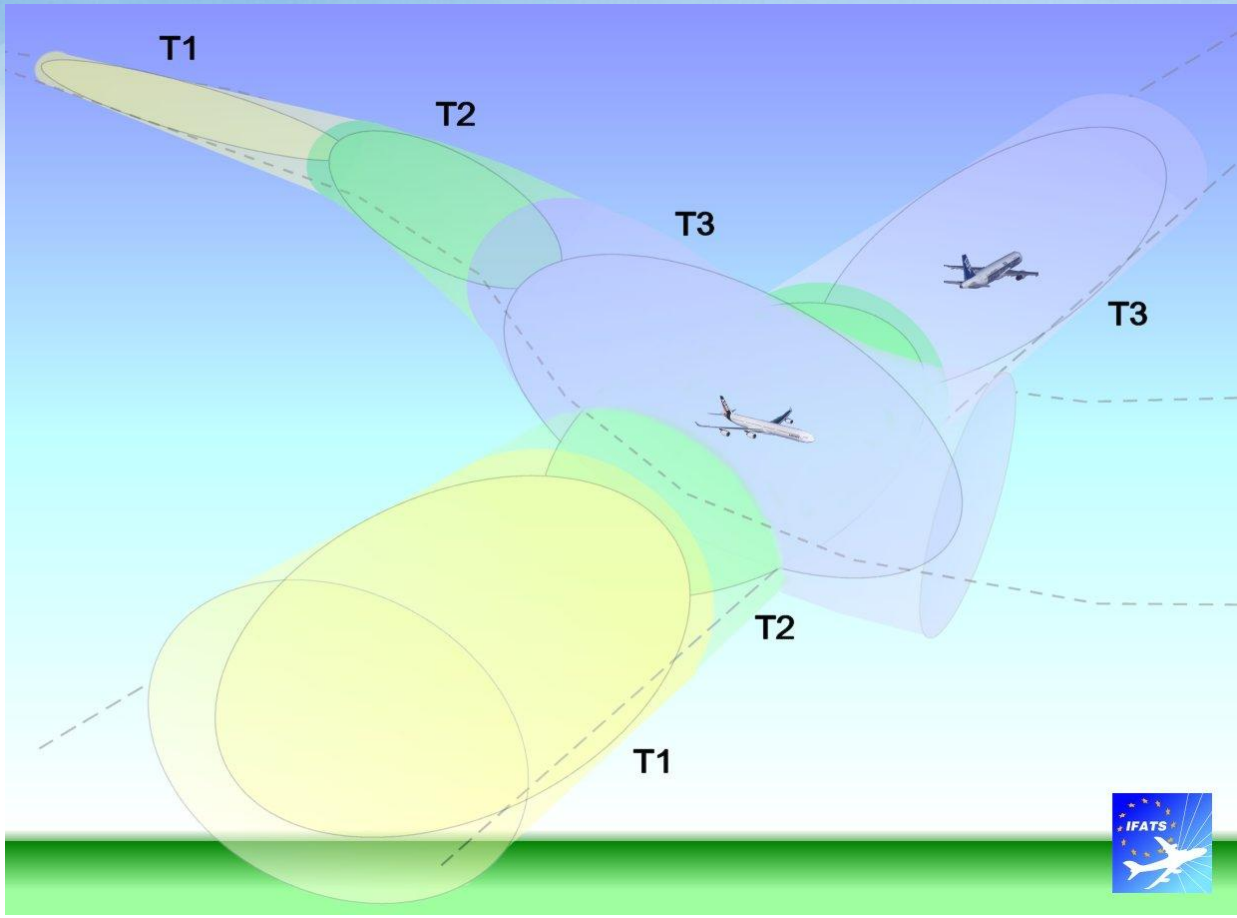
4D trajectory

- Being at a given geographical point at a given time (x, y, z, t)
- Drawbacks
 - compliance of the actually flown trajectory with the planned one to be constantly monitored by ATC
 - Challenging for a pilot or a controller to keep the aircraft on the planned 4D trajectory
 - Separation between aircraft
 - Prediction of the real 4D trajectory from the ground is difficult

4D contract

- Designed to solve the trajectory prediction problem
- Ground segment in charge of generating conflict-free 4D trajectories
- Aircraft assigned 4D contracts
 - Aircraft are in charge of monitoring their own compliance with the contract
 - Asking a new contract if necessary
- Aircraft are guaranteed to fly conflict-free trajectories
- No need for trajectory prediction from the ground

“4D tubes” in a “4D airspace”



4D contracts are arranged to avoid any “same time at same position” situation by speed and trajectory adjustments

Bubbles

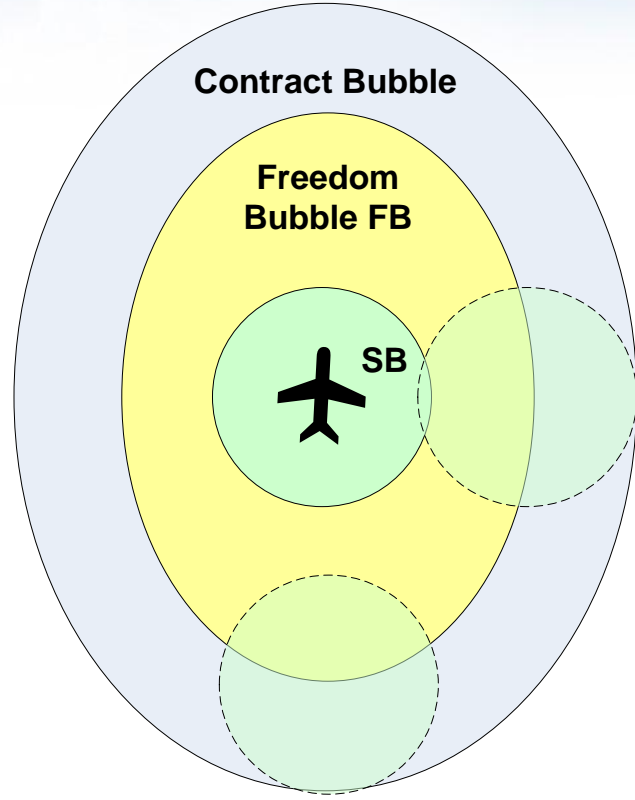
- En route, aircraft fly in 4D bubbles
 - Allowing to modify trajectory without asking for a new contract
 - Allowing ground speed variation
 - In order to follow the optimal Mach number
 - Ensuring separation with other traffic

- Conflict free traffic is guaranteed as long as all aircraft remain within their bubbles
 - This means that 4D contracts are respected both by aircraft and ATM
 - The aircraft asks for a new contract only when it knows it will fly out of its bubbles

- Bubble shape and size are function of the neighboring traffic

Bubbles

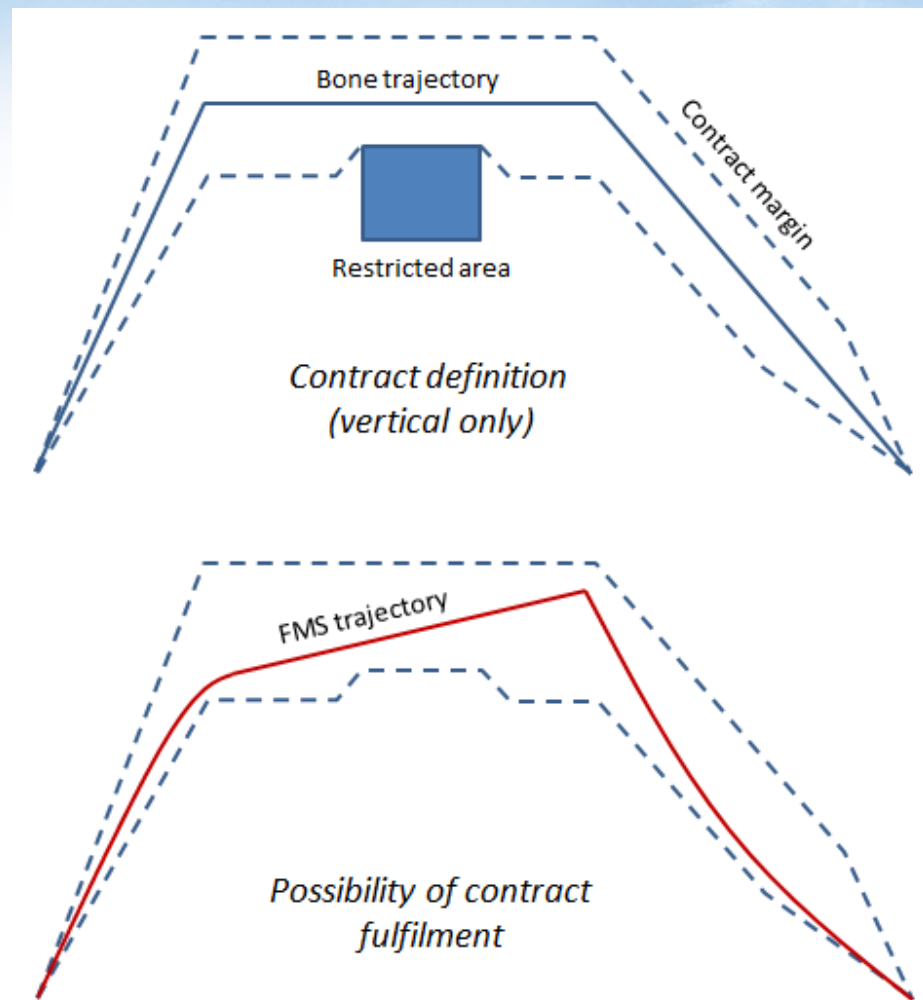
- Trajectory bone
- Margins around the aircraft
 - Safety Bubble
 - Linked to the aircraft
 - At any time, 2 SB must not intersect
 - Contract Bubble
 - Calculated by the ATSM to have conflict-free 4D contracts
 - At any time, 2 CB should not intersect
 - Freedom Bubble
 - Calculated by the FMS from CB and SB
 - Area where the CoG of the aircraft can be



4D contract = Bone + SB + CB

Trajectory management

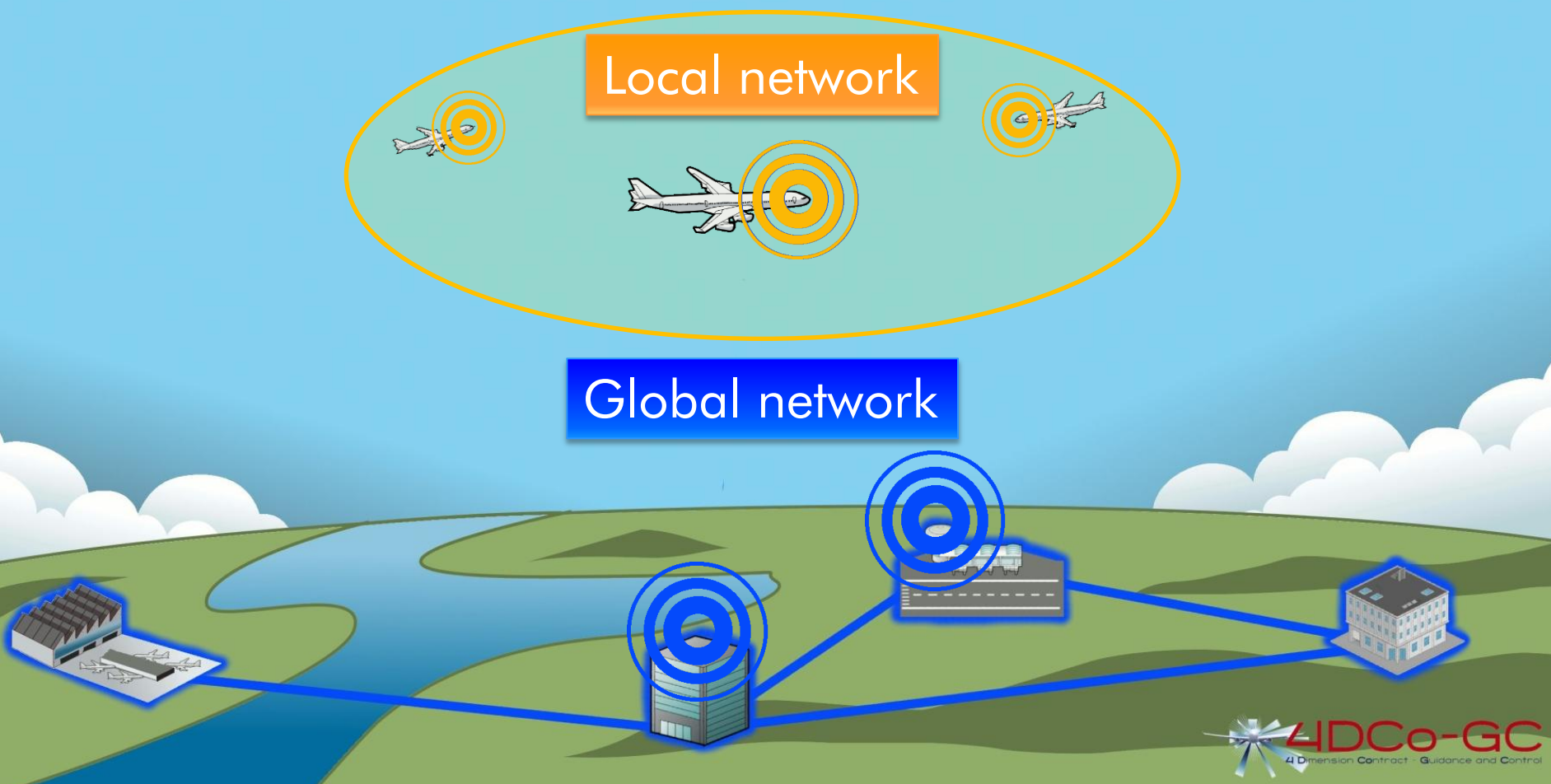
- 4D contract is assigned to the aircraft by the ATSM
- But the trajectory is calculated by the FMS
 - To comply with the 4D contract
 - To fit the airline priorities



“4D flight” overview

- 4D contracts generation
 - At a planetary scale, taking into account airlines wishes and airport capacity
 - Generation of conflict free flight paths → 4D contracts
- Departure
 - 4D contract updated just before the flight (during passenger boarding)
 - Slot assignment when the aircraft is ready
 - Automatic taxiing and direct take-off
 - Take off sequence optimized (aircraft size, weight, performance)
- En route
 - Aircraft follow 4D contracts as much as it can, or ask for a new one
- Arrival
 - Automatic landing with minimized taxiing

Network Centric Architecture



Non-nominal situations

- Failure management

- The failure is known
 - Automatic application of the implemented palliative strategy
 - The airline maintenance is made aware of the problem, real time
- The failure is new: no palliative strategy has been implemented
 - Aircraft state downloaded to a dedicated ground infrastructure
 - Aircraft specialists
 - High capabilities simulation means
 - Defined strategy sent back to the aircraft and applied
 - Feed back used to improve all the fleet

- Emergency situations

- Use of local network to get an onboard precise situation awareness
- Onboard self definition of emergency maneuver
- Use of global network, when possible, to get an “official” 4D contract