

Conflict resolution in autonomous aircraft operations

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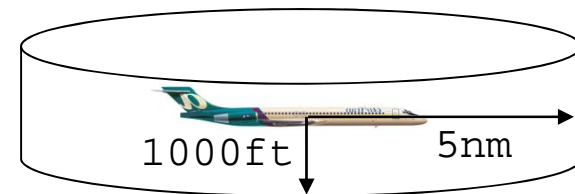
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Safety, conflict detection & resolution

- Safety primary consideration of air traffic management system
- In airborne operations in principle interested
 - Collision risk
 - Collision avoidance
- In practice introduce safety margin
 - Loss of separation
 - “Conflict”
- Conflict detection and resolution (CDR)



CDR steps

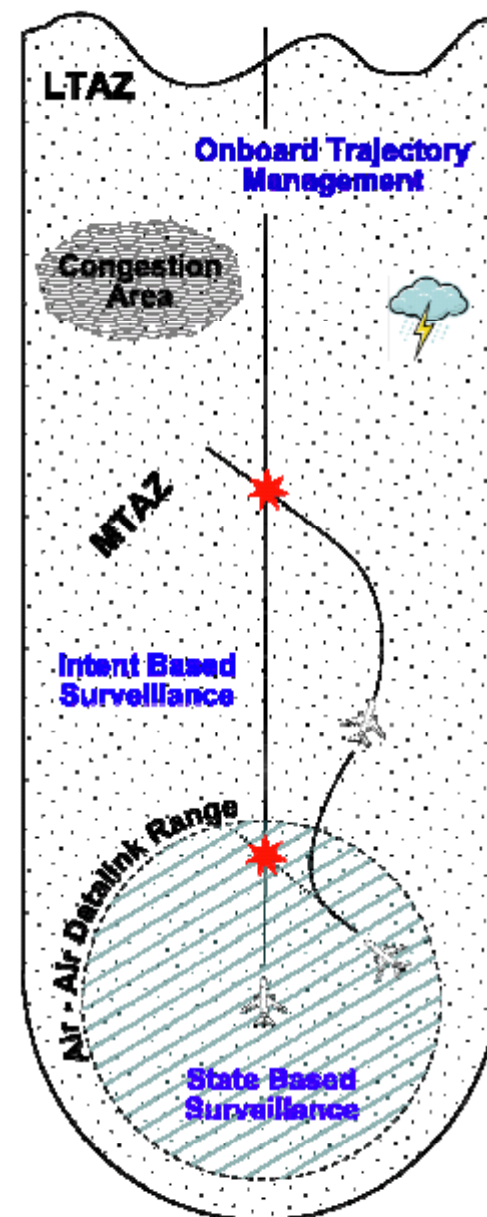
- Prevention of conflicts series of steps
- Trajectory prediction
 - Predict future positions of aircraft
 - Given all available information
- Conflict detection
 - Compare future positions
 - Determine whether loss of separation is likely
- Conflict resolution
 - Determine what to do to resolve the problem

Currently

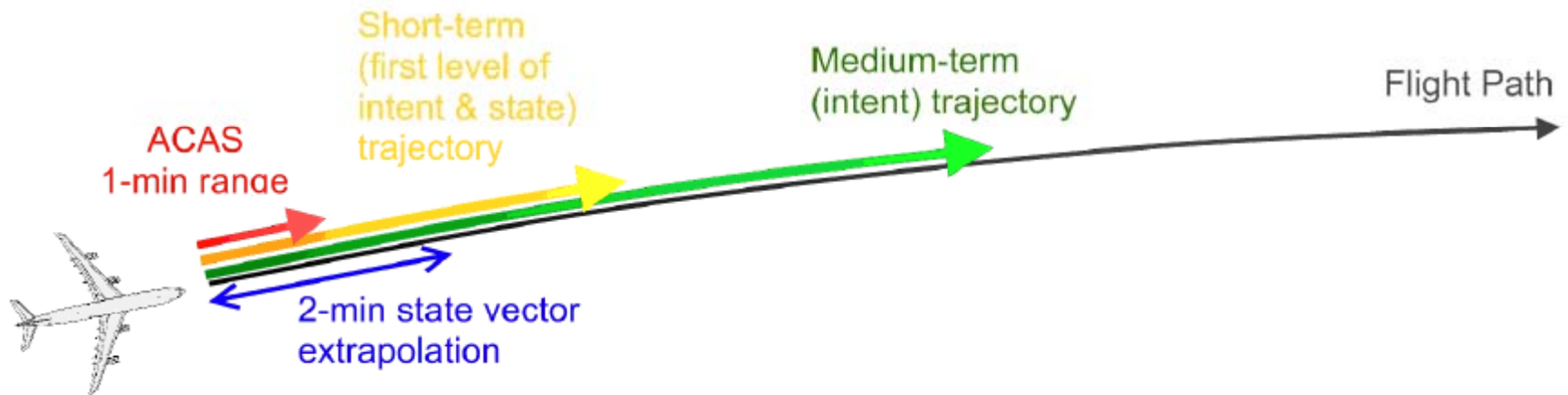
- Currently CDR
 - Ground based
 - Performed mostly by air traffic controllers
 - Centralized, coordinated
 - Intent of all aircraft known (flight plan, or RBT)
- With the notable exception of ACAS/TCAS
- By contrast, in self separation airspace
 - CDR airborne
 - Responsibility delegated to aircraft/pilot
 - Distributed, decentralized
 - Explicit vs. implicit (or even no) coordination
 - Intent of other aircraft not necessarily known

Different levels of CDR

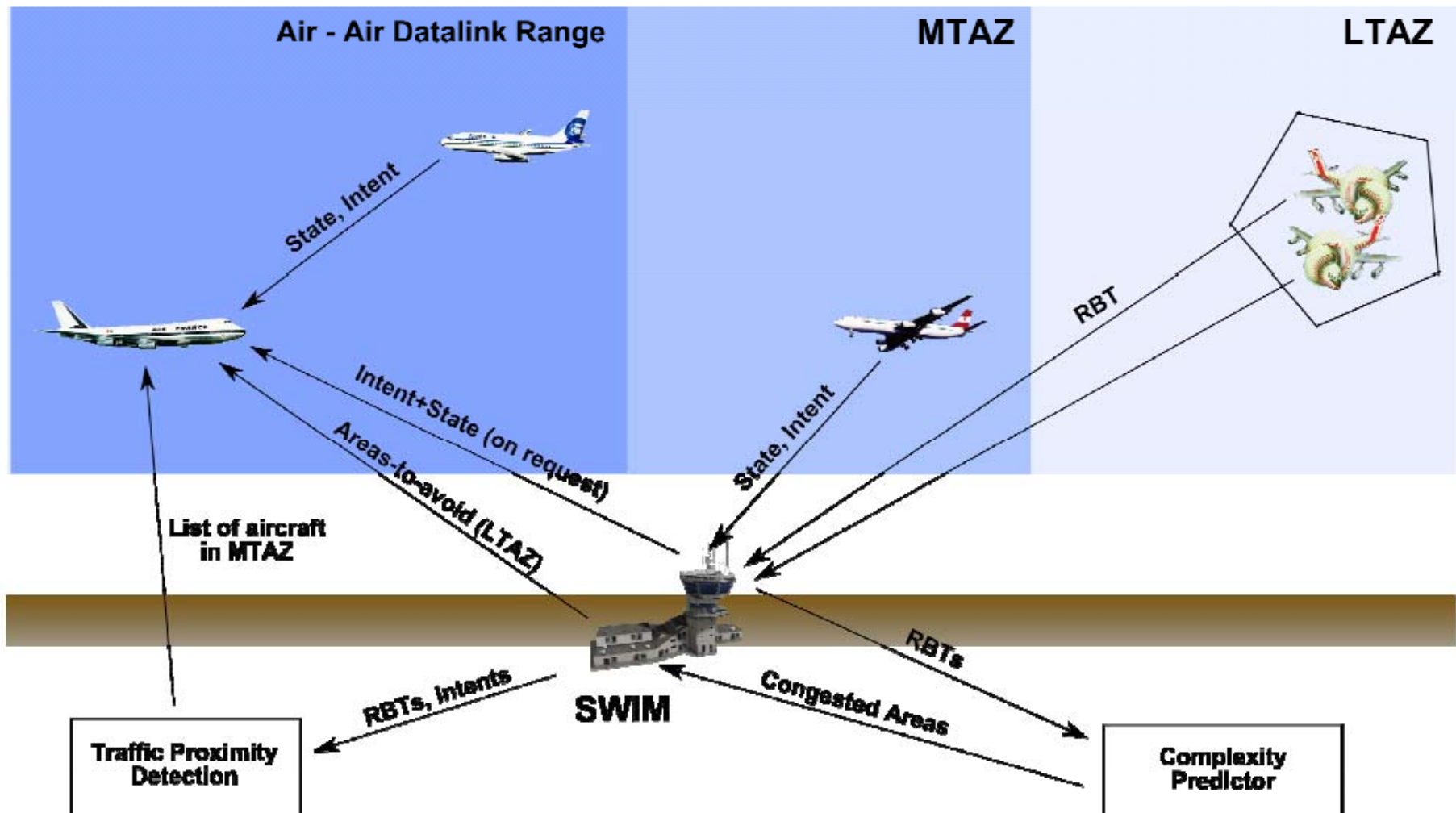
- Long term CDR
 - Long term alert zone
 - > 30 minutes into the future
- Mid term CDR
 - Mid term alert zone
 - ~ 20 minutes into the future
- Short term CDR
 - Short term alert zone
 - < 5 minutes into the future
- ACAS/TCAS
 - Last resort safety net
 - ~ 1 minute into the future



Different levels of CDR: Temporal

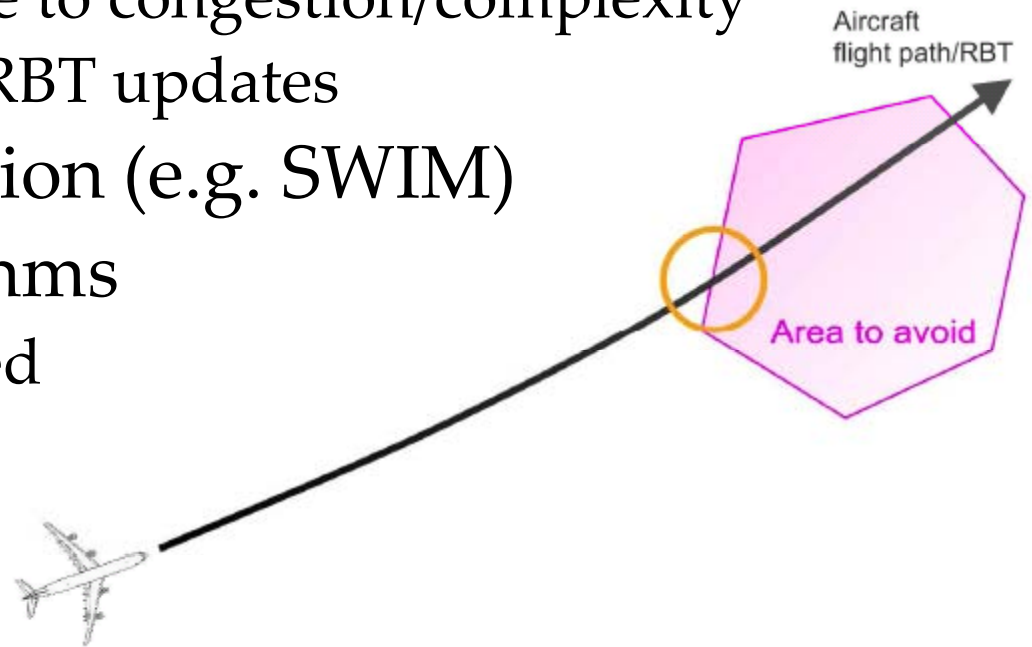


Different levels of CDR: Information



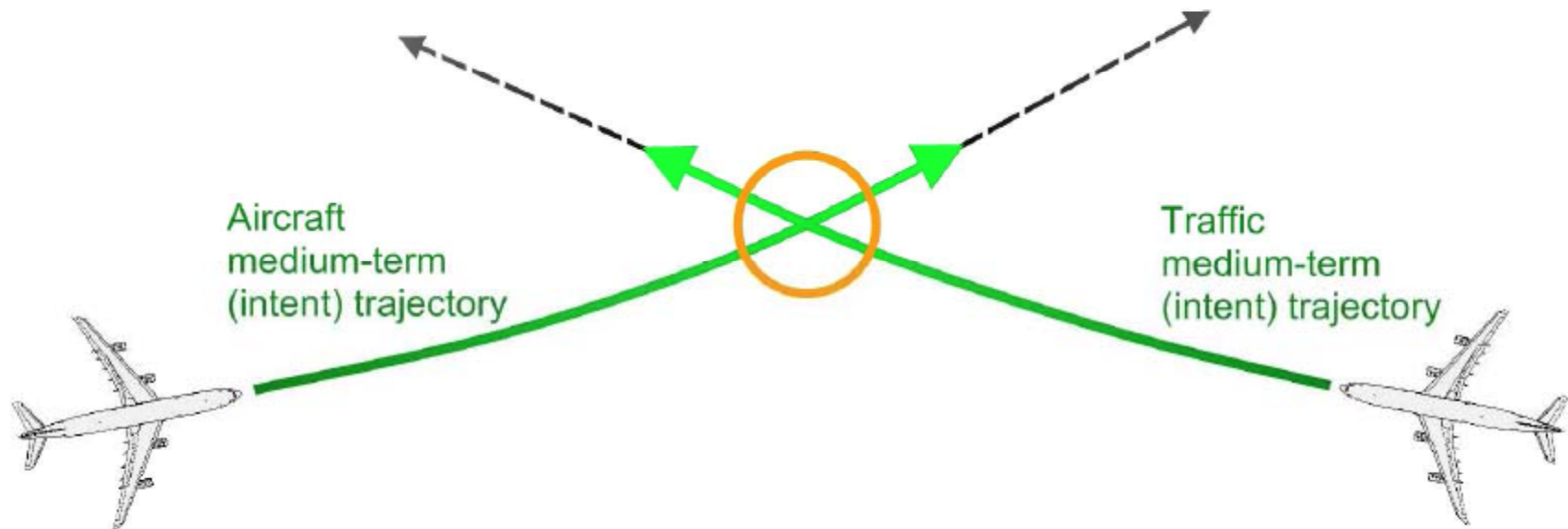
Long term CDR

- Horizons of tens of minutes to hours
- Not safety critical at this range
- On board trajectory management
 - Areas to avoid due to weather
 - Areas to avoid due to congestion/complexity
 - Schedule tuning, RBT updates
- “Global” information (e.g. SWIM)
- Candidate algorithms
 - Optimization based



Mid term CR

- Horizons of ~20 minutes
- Safety critical, conflict most important concern
- Access to intent of other aircraft
 - E.g. through ground based information system



Mid term CR

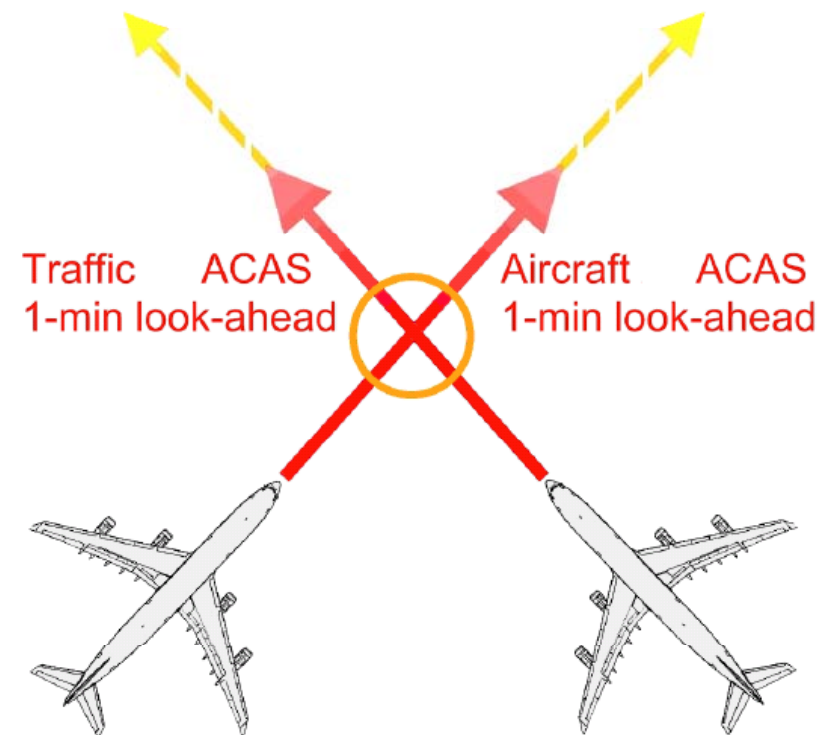
- Planning/execution horizons of several minutes
- Enough time to compute resolution
 - E.g. through optimization
- Enough time to coordinate with other aircraft
 - E.g. broadcast solution for others to take into account
 - Possibly better suited for explicit coordination

Short term CR

- Horizons of < 5 minutes
- Safety critical, last line of defense before ACAS
- Short planning/execution horizons
 - Fast, possibly implicitly coordinated maneuvers
 - E.g. robotic path planning
- Access to potentially faster air-air data-link
- State based
 - Measured directly by on-board equipment
 - E.g. positions and velocities of other aircraft
- First level of intent
 - Communicated through air-air data-link
 - E.g. next goal of each aircraft

ACAS

- Horizons of ~1 minute
- Last safety net
- State extrapolation
- ACAS interference concern for other CDR levels
- E.g. avoid creating 2 minute state conflict



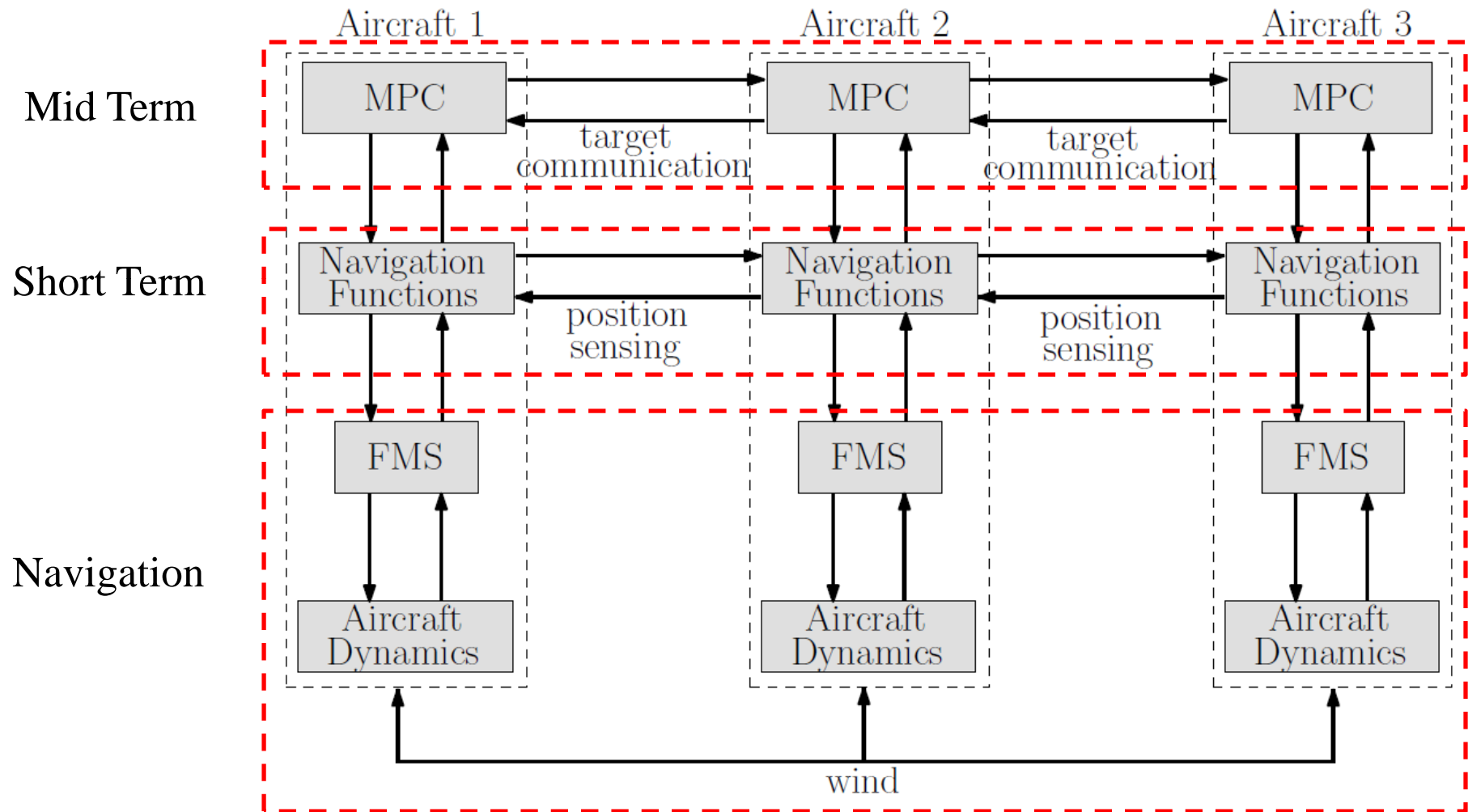
Issues

- Coordination
 - Centralized solution
 - Explicit
 - Implicit
 - None
- Available information
 - Global
 - Intent
 - First level intent
 - State
- Priorities
 - Fixed, variable, ...
- Sources of information
 - Measured on board
 - Air-air data-link
 - Ground based support
 - SWIM
- Human factors
 - Do pilots need to understand maneuver?
 - Do they need to execute it?
 - Do they need alternatives?
- Certification, legal, ...

Overview

- Conflict resolution in NASA free flight concept
- Short term conflict resolution in iFly concept
- Mid term conflict resolution in iFly concept
- Touching upon many of these issues

Hierarchy in iFly concept



Thank you for your attention!

