Controller Managed Spacing Studies

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Controller Managed Spacing Studies

Motivation

Enable quiet, fuel efficient Optimized Profile Descent operations with high throughput.

Objective

Determine through fast-time and human-in-the-loop simulations how well controllers with and without advisory tools and enhanced displays based on 4D trajectories can cope with disturbances and manage spacing of arrival aircraft on RNAV RNP routes with Optimized Profile Descents.

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Operational Concept for Controlling Arrival Aircraft on RNAV RNP / OPD routes

Time-based metering provides runway arrival schedule and time constraint for inbound aircraft.

En route speed assignments deliver aircraft so they are correctly spaced for descending on the RNAV RNP / OPD profile.

Flight crews fly VNAV descents along RNAV RNP route – largely without controller intervention.

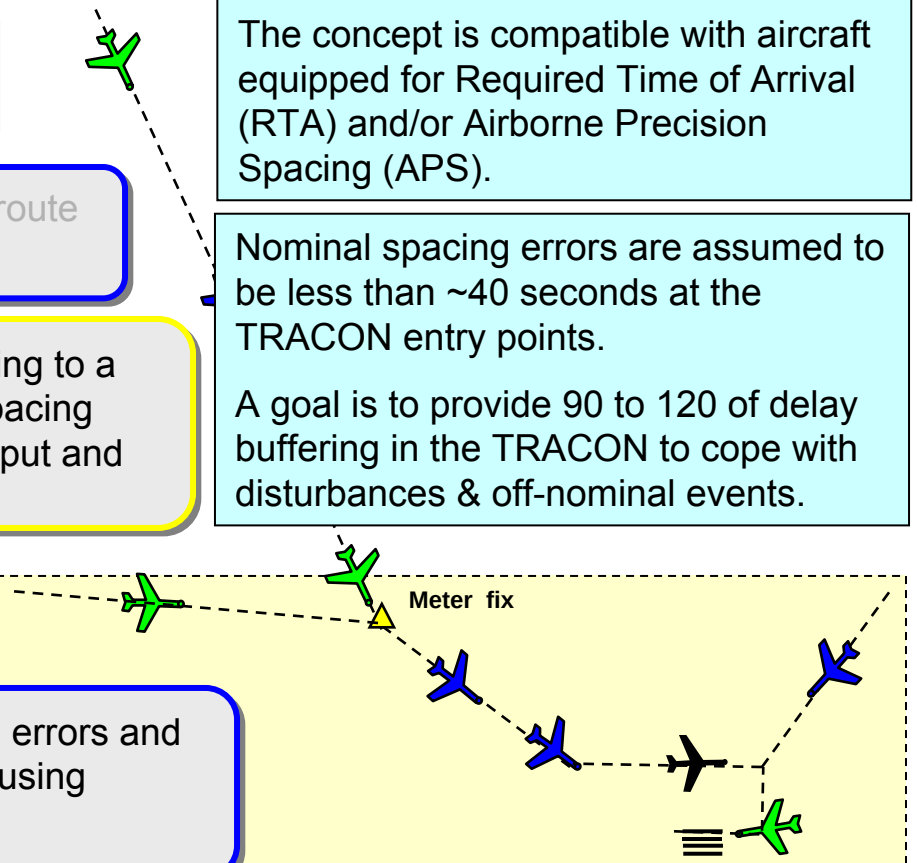
Aircraft are delivered to TRACON boundary according to a runway based time schedule. Aircraft arrive with spacing errors that need to be reduced to maximize throughput and minimize spacing violations.

All aircraft are assumed to be FMS & ADS-B equipped and a significant number of the aircraft are assumed to be equipped with data link for trajectory clearance delivery.

The concept is compatible with aircraft equipped for Required Time of Arrival (RTA) and/or Airborne Precision Spacing (APS).

Nominal spacing errors are assumed to be less than ~40 seconds at the TRACON entry points.

A goal is to provide 90 to 120 of delay buffering in the TRACON to cope with disturbances & off-nominal events.



Focus of these studies:

TRACON controllers correct residual spacing errors and cope with disturbances & off-nominal events using displays and tools based on 4D trajectories.

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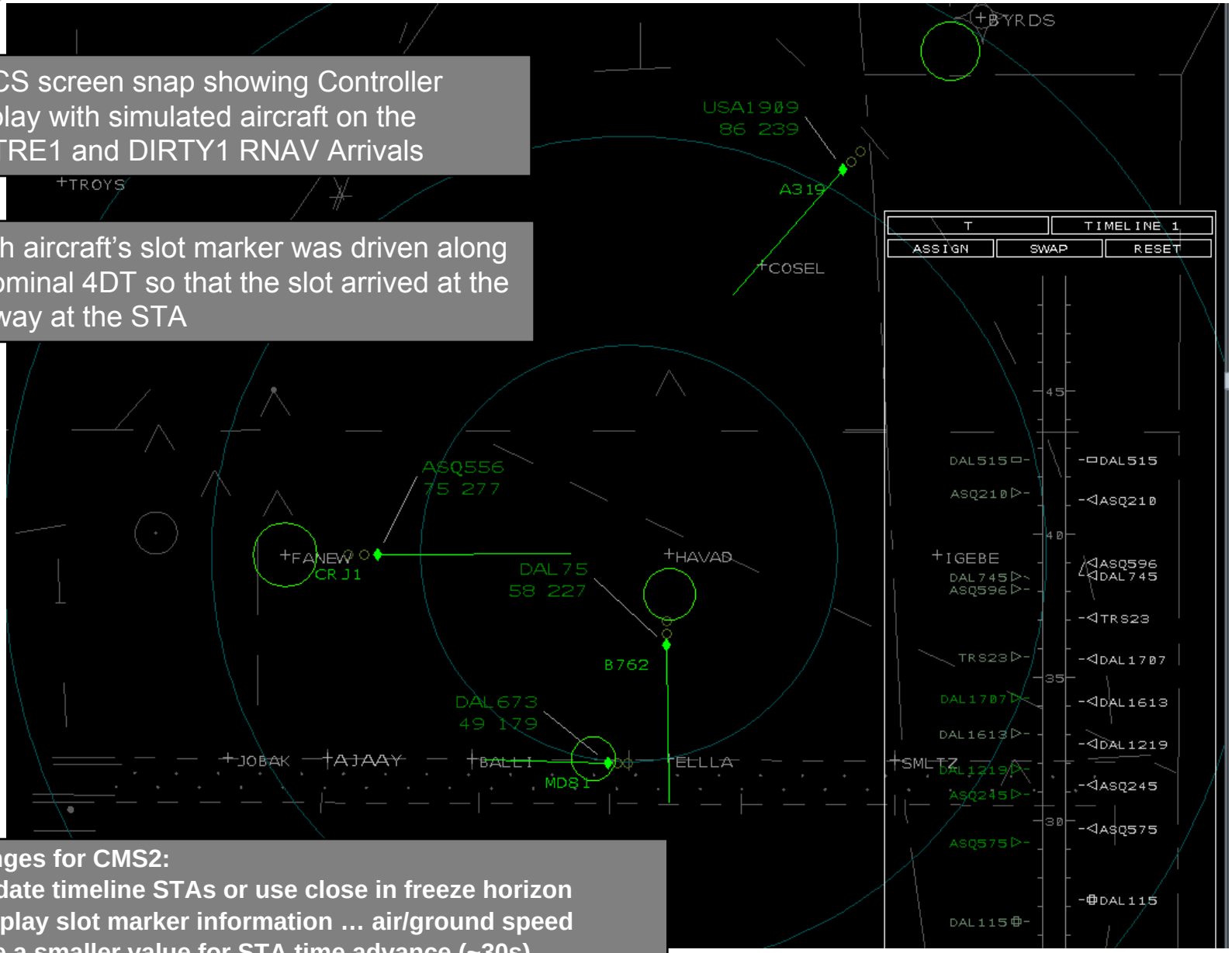
Controller Tools for CMS1 Study

MACS screen snap showing Controller Display with simulated aircraft on the NOTRE1 and DIRTY1 RNAV Arrivals

Each aircraft's slot marker was driven along a nominal 4DT so that the slot arrived at the runway at the STA



Changes for CMS2:

- **Update timeline STAs or use close in freeze horizon**
- **Display slot marker information … air/ground speed**
- **Use a smaller value for STA time advance (~30s)**

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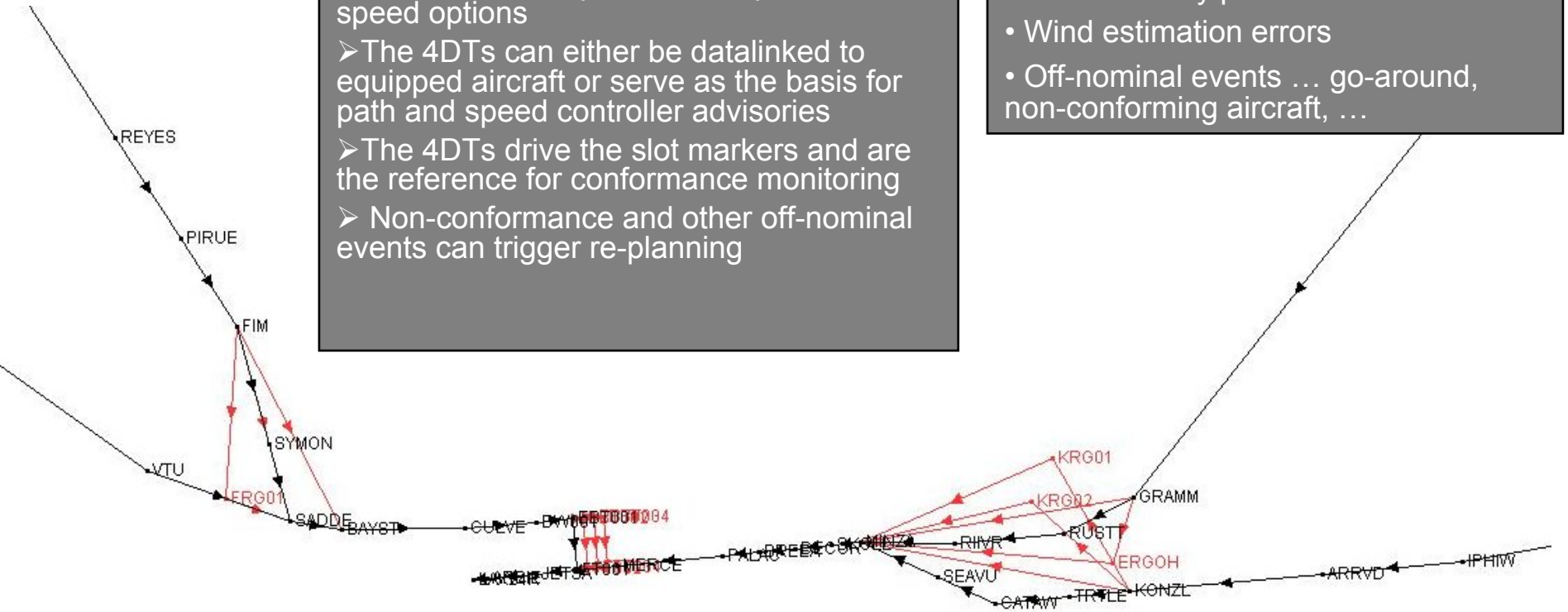
Concept for Controller Tools for CMS2 Study

Control concept:

- The ground automation computes 4DTs for arriving aircraft that are conflict free and deliver aircraft to the runways with high throughput
- 4DTs are based on nominal RNAV RNP/OPD routes plus defined path and speed options
- The 4DTs can either be datalinked to equipped aircraft or serve as the basis for path and speed controller advisories
- The 4DTs drive the slot markers and are the reference for conformance monitoring
- Non-conformance and other off-nominal events can trigger re-planning

Possible experimental variables:

- 4DT based path and speed advisory tool … 1 to N REPLANS
- Aircraft equipage mix: DL, RTA, APS
- Size of residual spacing errors at the TRACON entry points
- Wind estimation errors
- Off-nominal events … go-around, non-conforming aircraft, …



Goal: A control strategy that enables quiet, fuel efficient Optimized Profile Descent operations with high throughput and is robust to disturbances and off-nominal events while keeping aircraft on RNAV routes.

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Slot Markers in CMS1 and CMS2

In both CMS1 and CMS2 concepts the slot marker for an aircraft is driven along a 4DT and arrives at the runway at the STA.

In the CMS1 concept the slot marker for an aircraft is driven along a prespecified nominal 4DT from a terminal area entry point to a runway.

In the CMS2 concept the slot marker for an aircraft is driven along a custom 4DT from the aircraft present position to a runway. If the aircraft is datalink equipped this 4DT could be sent to the aircraft as the clearance. If the aircraft is not datalink equipped it serves as the basis for controller advisories. In either case this 4DT provides the reference for conformance checking.

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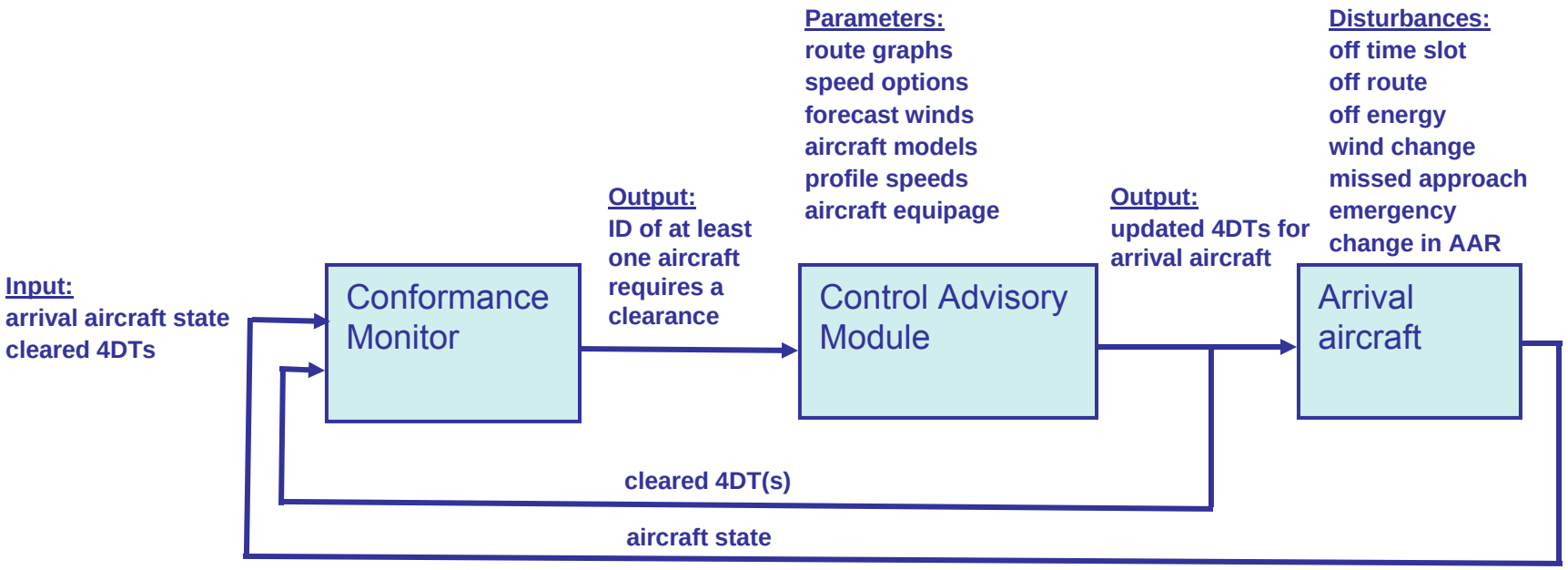
TRACON Arrival 4DT Control Concept



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Activities

- Control authority & delay buffering analysis of routes for CMS2 study
- Fast-time simulation and analysis of various control strategies
- HITL CMS2 study with path and speed controller advisory tools in Fall 2009

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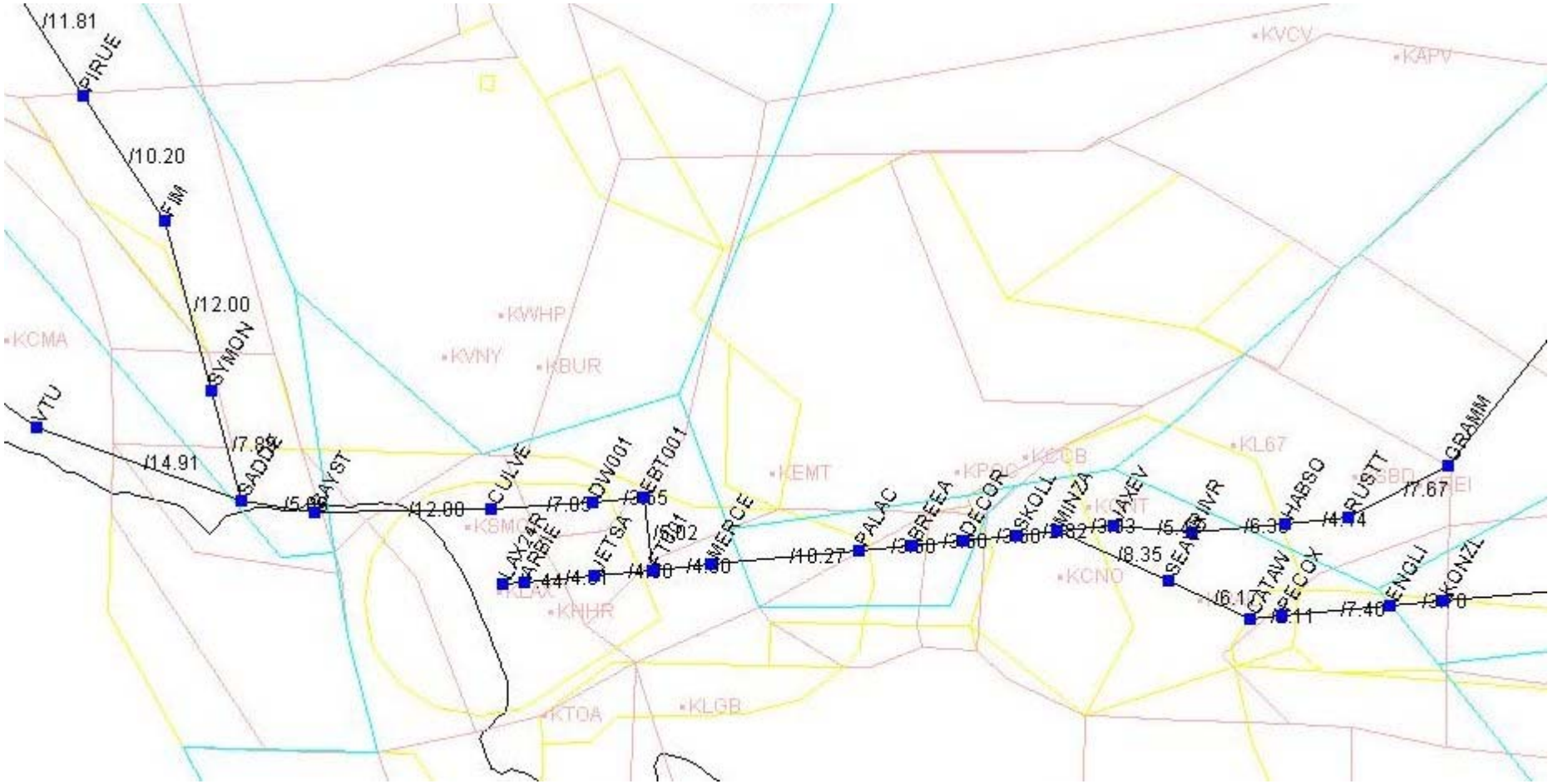
Initial RNAV Routes for CMS2



Nominal route description

ARRIVAL LAX LAX24R AVE JET NW2_LAX24R 280 200 BSR, AVE, DERBB, REYES, FIM, SYMON, SADDE, BAYST, SMO:AT10000:S230, SAPPI:AT4600:S180, MERCE:AT4100:S170, JETSA:AT2200, ARBIE:S150, LAX24R:AT117:S135

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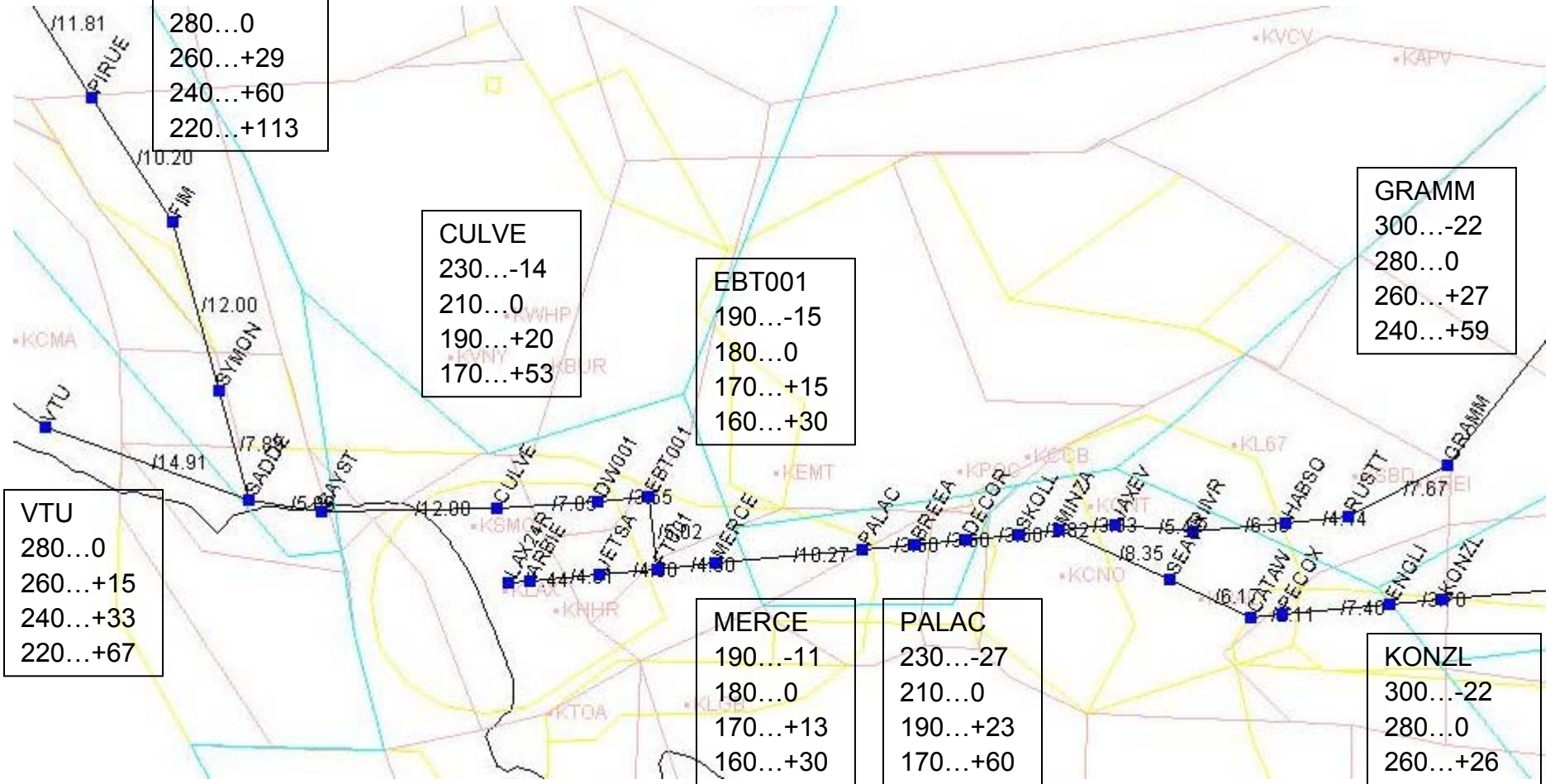
Time of arrival control authority with strategic speed



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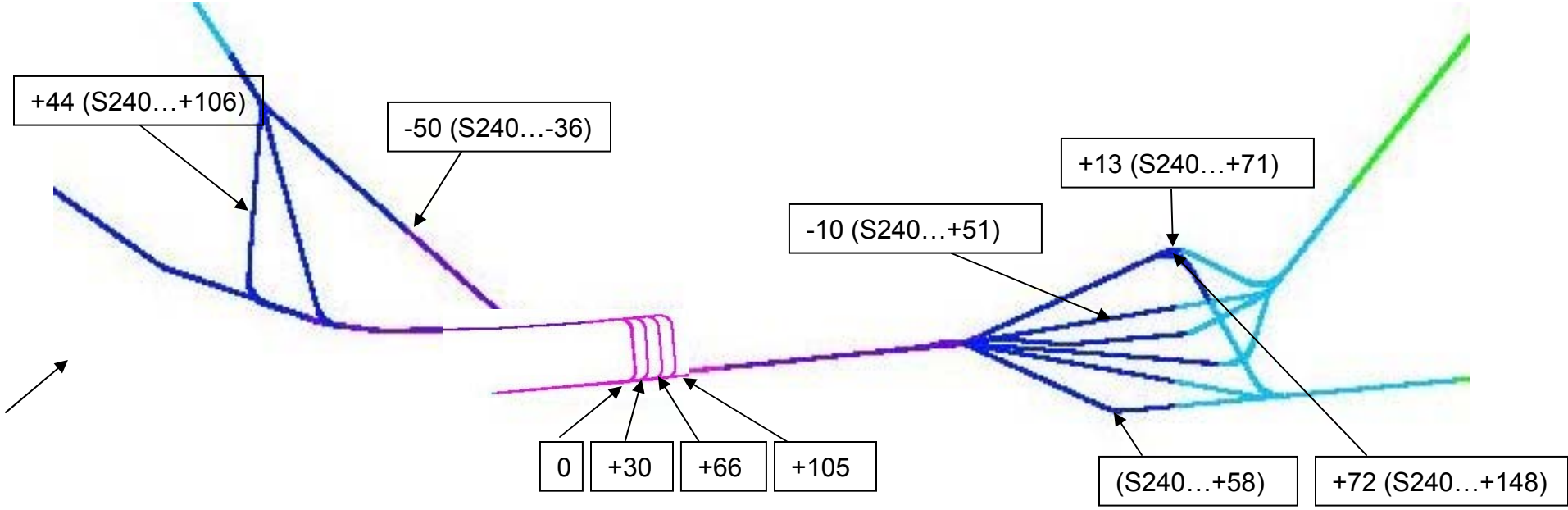
Time of arrival control authority with strategic path & speed



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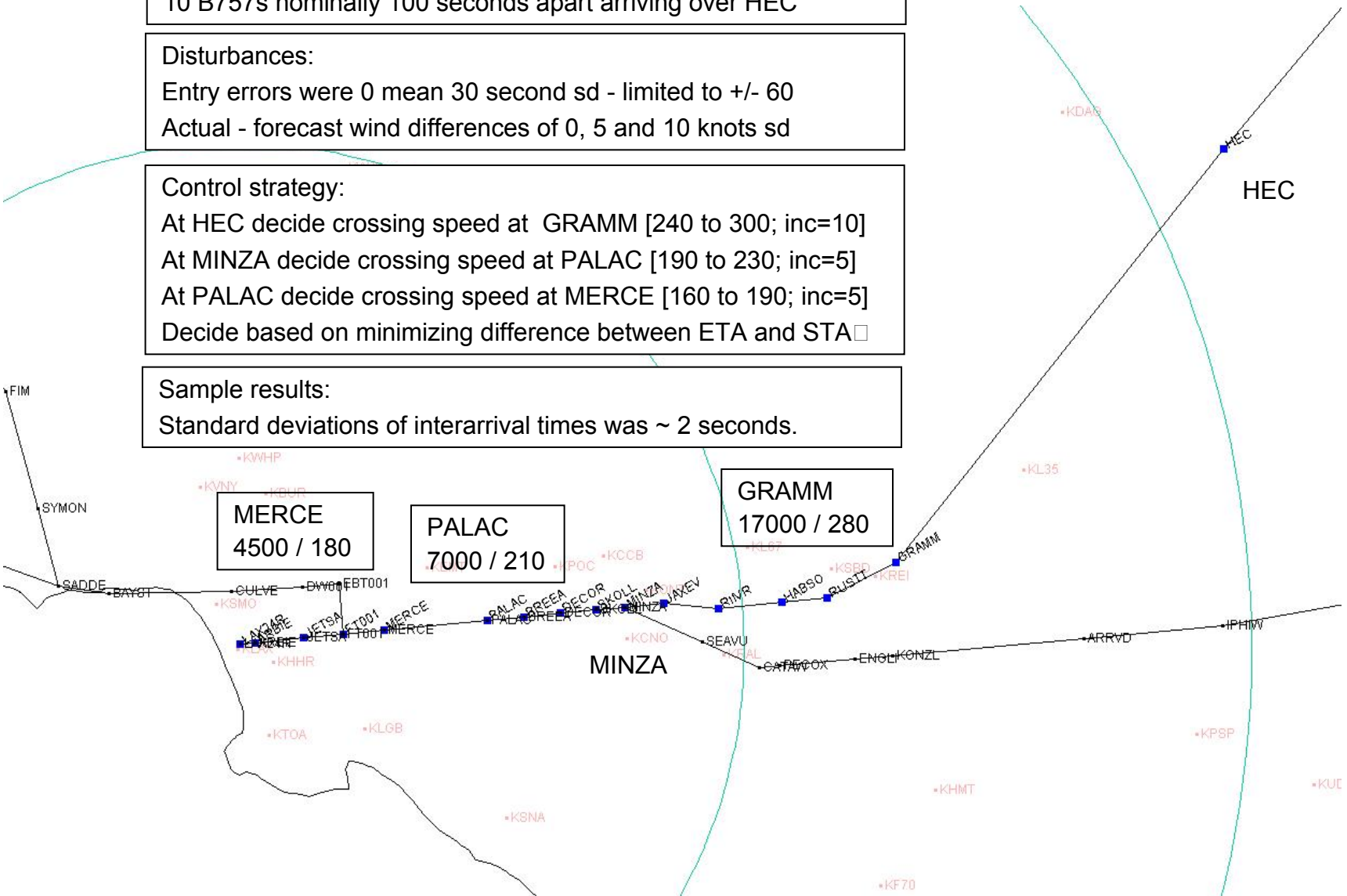
Sample control with strategic speed

Scenario:
10 B757s nominally 100 seconds apart arriving over HEC

Disturbances:
Entry errors were 0 mean 30 second sd - limited to +/- 60
Actual - forecast wind differences of 0, 5 and 10 knots sd

Control strategy:
At HEC decide crossing speed at GRAMM [240 to 300; inc=10]
At MINZA decide crossing speed at PALAC [190 to 230; inc=5]
At PALAC decide crossing speed at MERCE [160 to 190; inc=5]
Decide based on minimizing difference between ETA and STA

Sample results:
Standard deviations of interarrival times was ~ 2 seconds.



Thank you!

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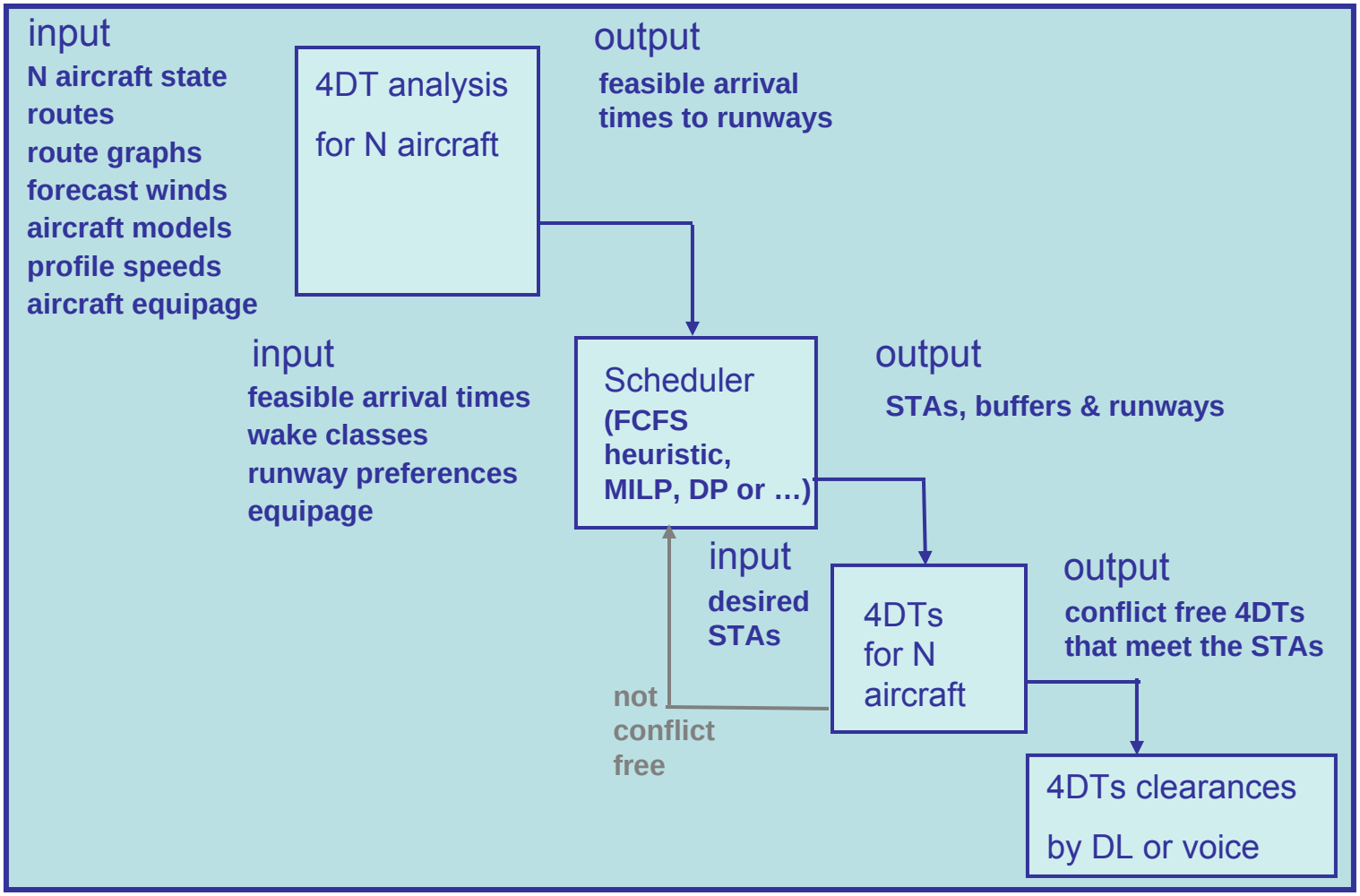
Control Advisory Module



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