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Design of an airborne spacing director to minimise pilot speed actions



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Plan of the presentation

- Objective
- Operational concept
 - Airborne spacing 'Remain behind'
- Airborne spacing director
 - Requirements
 - Architecture
 - Design
- Test scenarios
 - 1) Airborne spacing director validation
 - 2) Sequence of 4 aircraft
- Results
- Conclusion



© EEC cockpit display remain behind

Objective

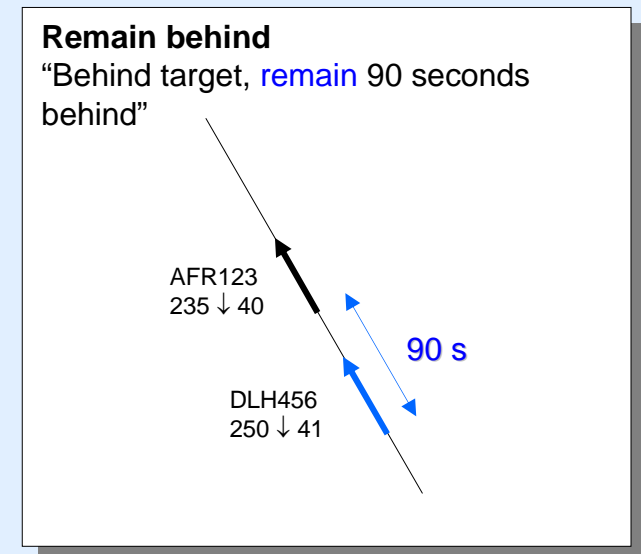
- To prototype and test a flight deck tool 'airborne spacing director' for assisting pilots establish and maintain a required time delay behind a lead aircraft.
 - Main aim to minimise the number of manual speed adjustments while meeting a given level of spacing performance.
- Building on previous work
 - Automatic CAS control -> Continuous suggested CAS for pilot -> Filtered with 5 knot increment
 - Problem – high frequency of manual speed changes ~1 per minute



© EEC multi-aircraft cockpit simulator

Operational concept

- **Airborne spacing**
 - New task allocation between controllers and flight crew
 - Set of new spacing instructions where the flight crew can be tasked by the controller to maintain a given spacing (in time or in distance) with respect to a designated aircraft
- **Sequencing applications in terminal areas**
 - Remain/heading then remain behind
 - Merge/heading then merge behind
- **Remain behind**
 - Maintain spacing through speed adjustments

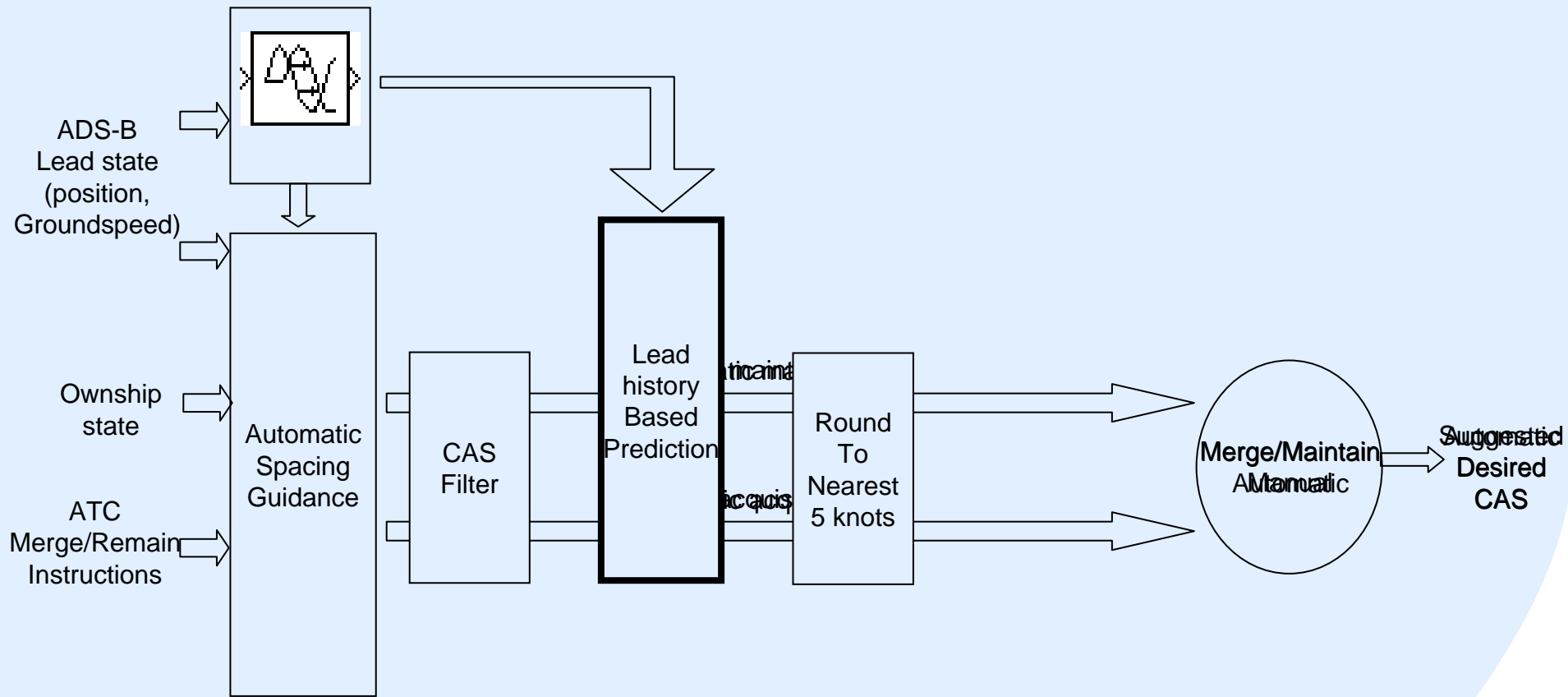


Airborne spacing director: requirements

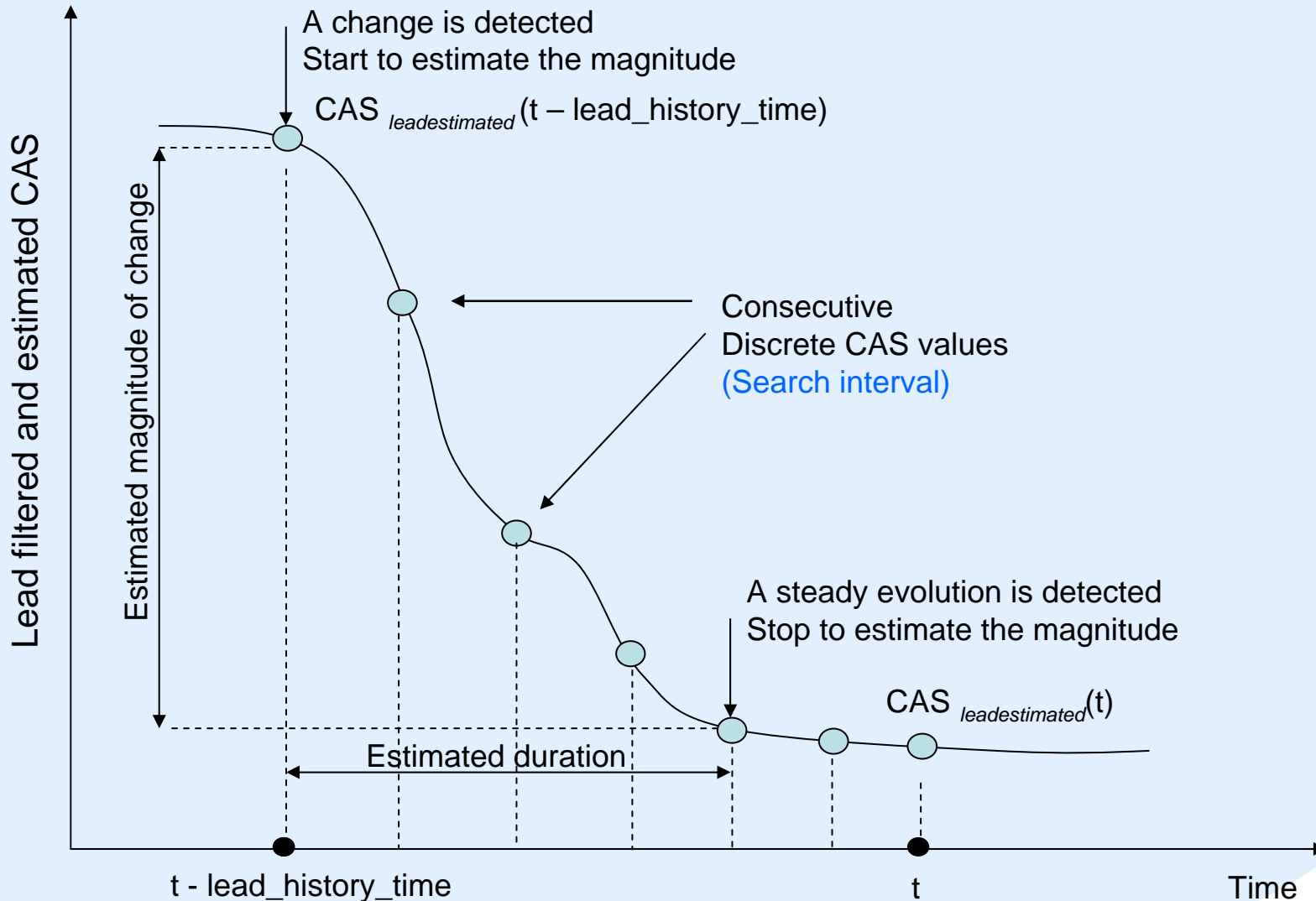
Requirement type	Performance parameter	Requirement
Accuracy	Spacing error	Attain and maintain: spacing error within mean ≤ 2.5 s and standard deviation < 1.25 s
Stability	Trail demanded CAS variation	Trail CAS overshoot due to a step demand should be no greater than 5 knots.

Design constraint type	Constraint parameter	Design constraint
Human factors	Time between consecutive CAS actions	Mean interval between speed actions $>$ than 3 minutes ± 30 s standard deviation
Human factors	Trail demanded CAS variation	CAS changes restricted to multiples of 5 knots

Airborne spacing director: architecture

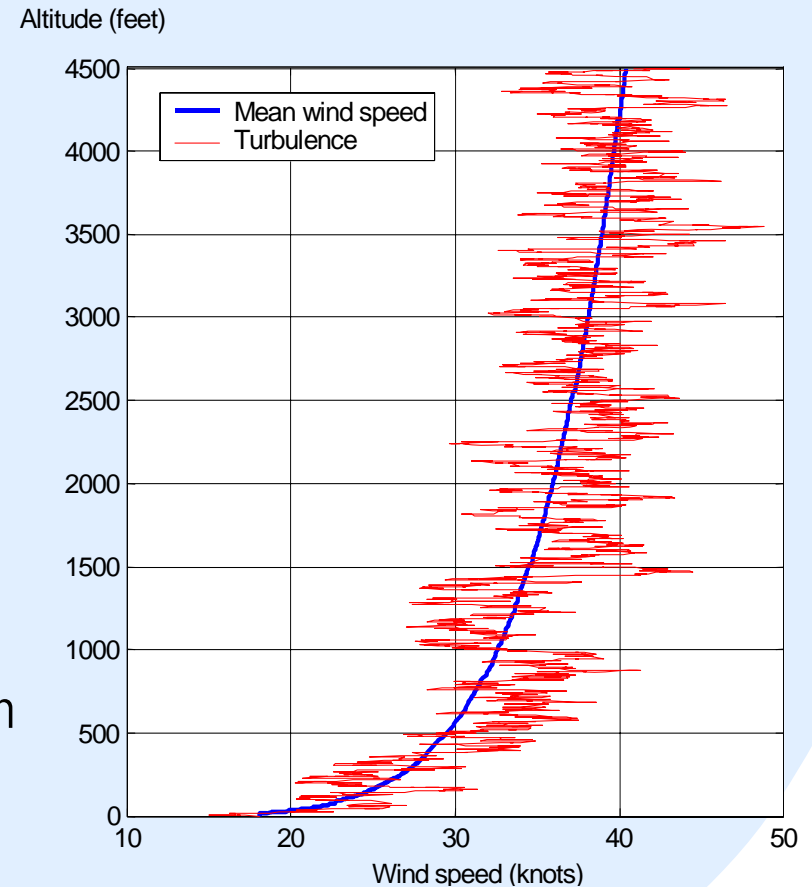


Airborne spacing director: design

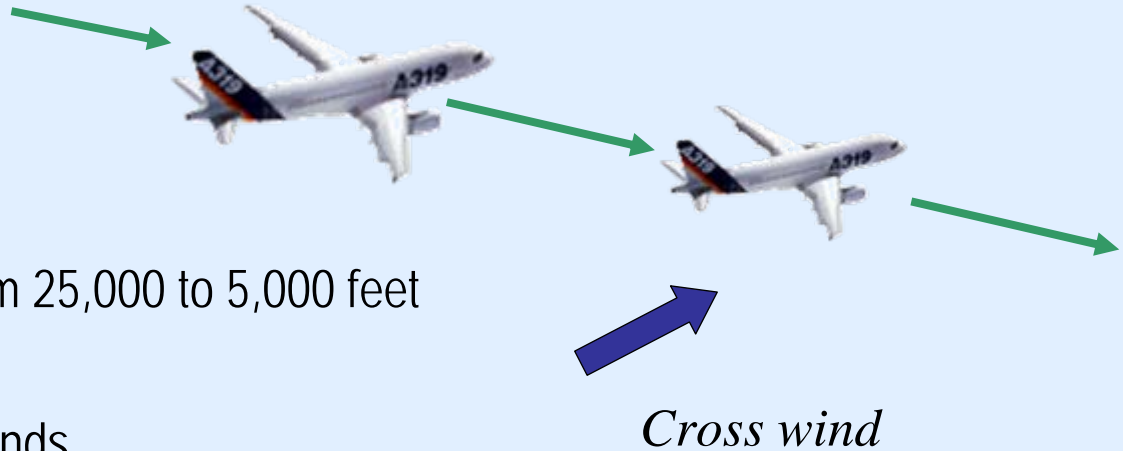


Modelling environment: aircraft and wind

- **Aircraft model:**
 - All aircraft are Airbus 320
 - Point mass with bank angle, thrust, lift and drag models validated by NLR
 - Pilot reaction: constant 5 s time delay
- **Wind model**
 - Joint Aviation Requirements-All Weather Operations autoland certification process (JAR-AWO 07/03-13, 1996)
 - Turbulence: gaussian distribution based on a Dryden spectrum
 - Disturbances of airspeed and angle-of-attack



Test scenario (1): airborne spacing director validation



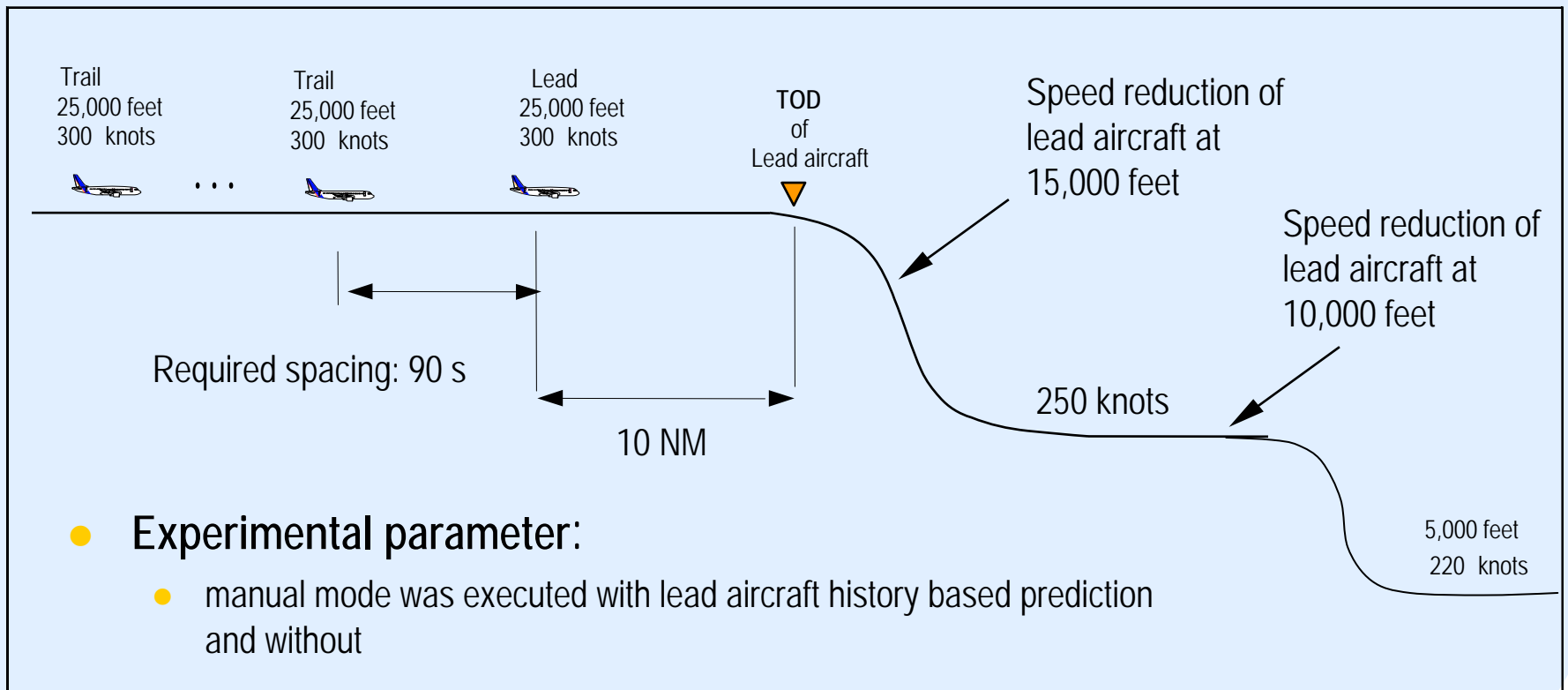
- **Scenario:**

- Two aircraft in descent from 25,000 to 5,000 feet
- No initial spacing error
- Required spacing: 90 seconds
- Light turbulent crosswind

- **Experimental parameters:**

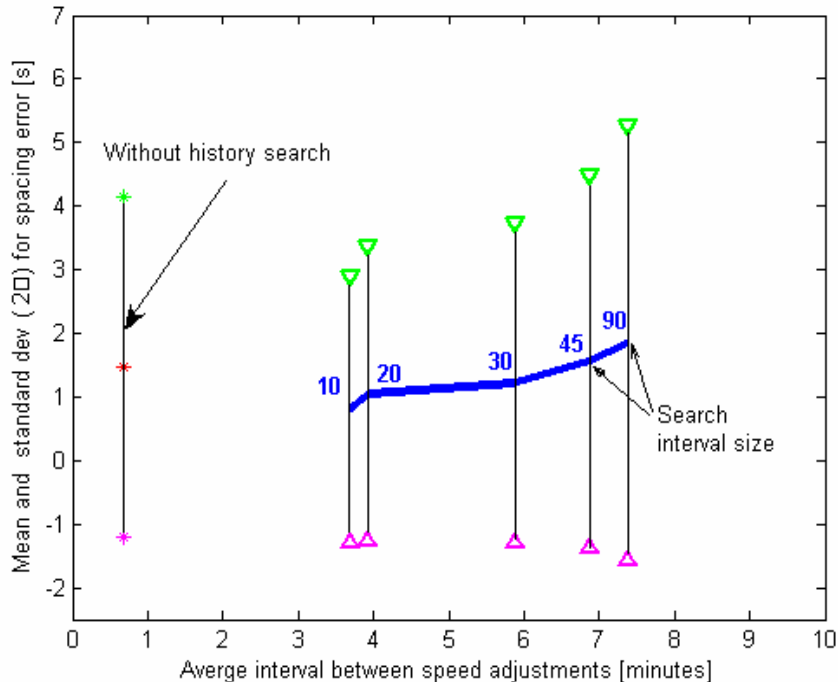
- Constant search interval of lead CAS history was varied between [10, 20, 30, 45 and 90] seconds
- Lead CAS profile: five lead descent profiles recorded from real-time simulations

Test scenario(2): sequence of 4 aircraft

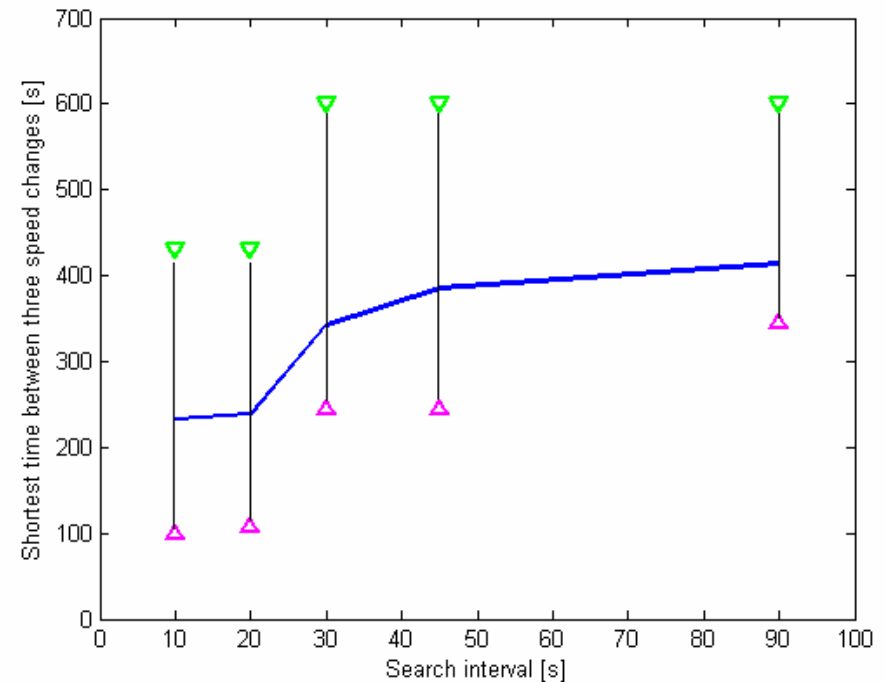


(All speeds in CAS, search interval fixed at 30s)

Results(1): airborne spacing director validation

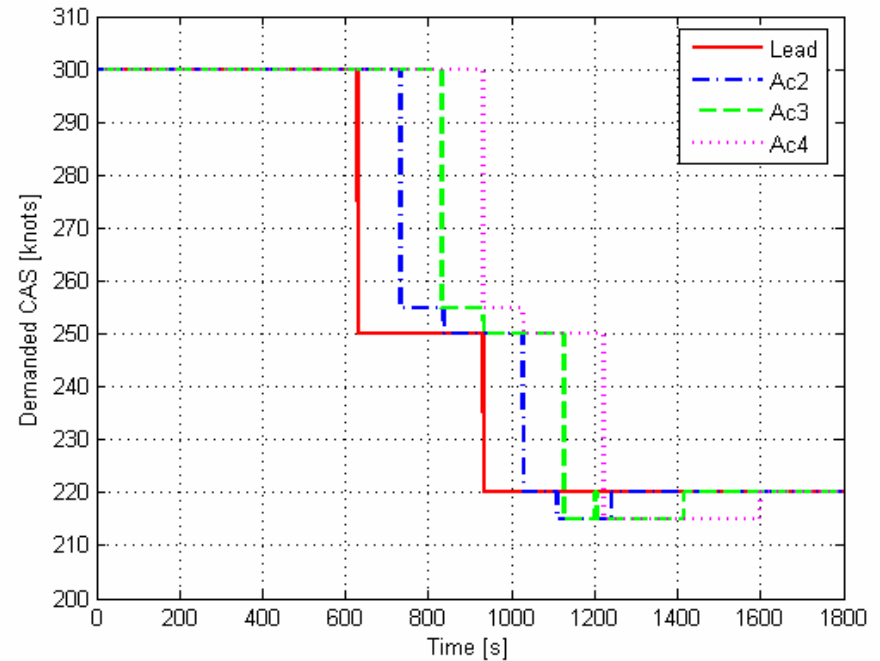
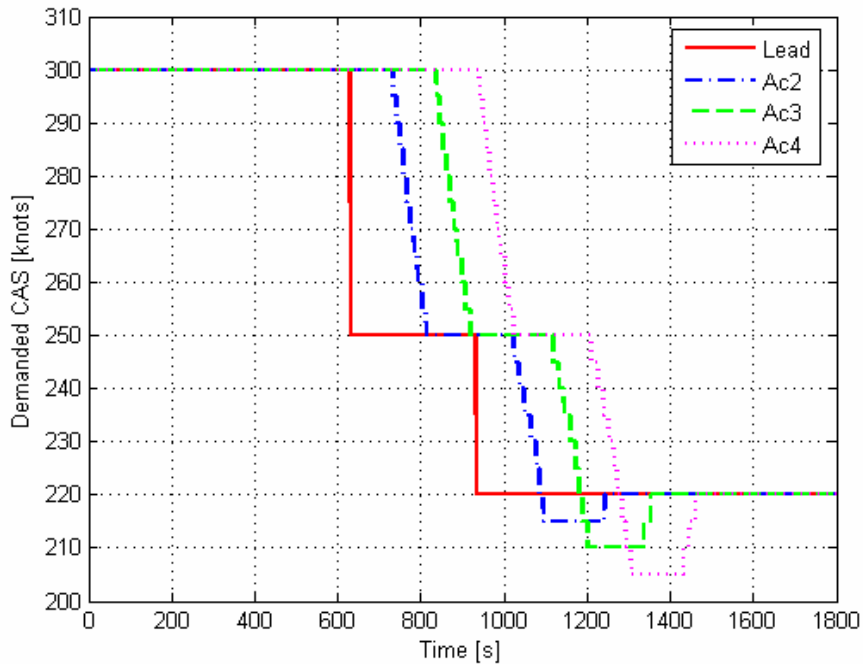


Mean spacing error as function of pilot activity for various search intervals (10, 20, 30, 45 and 90 s)



Shortest time between three consecutive speed actions as function of search intervals

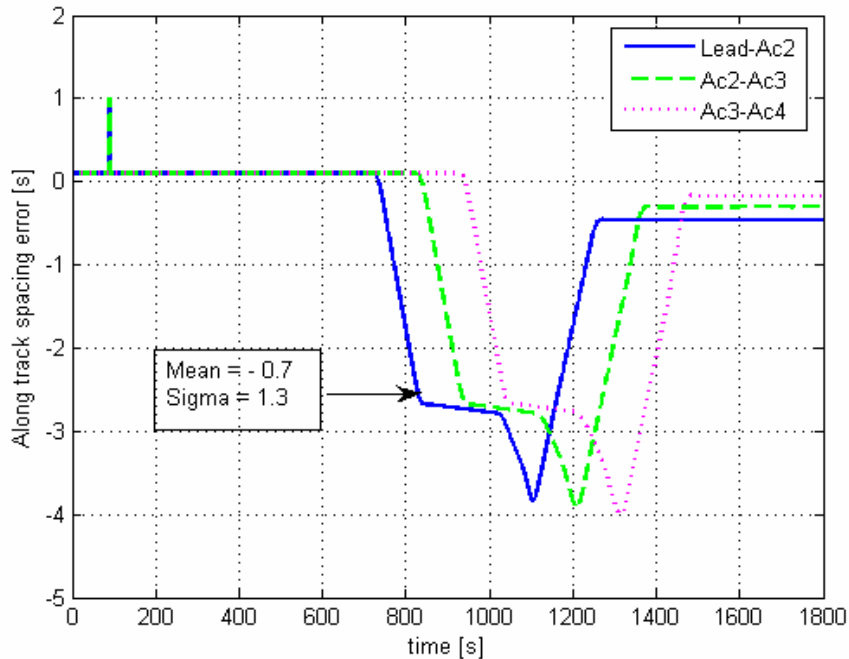
Results(2): sequence of 4 aircraft



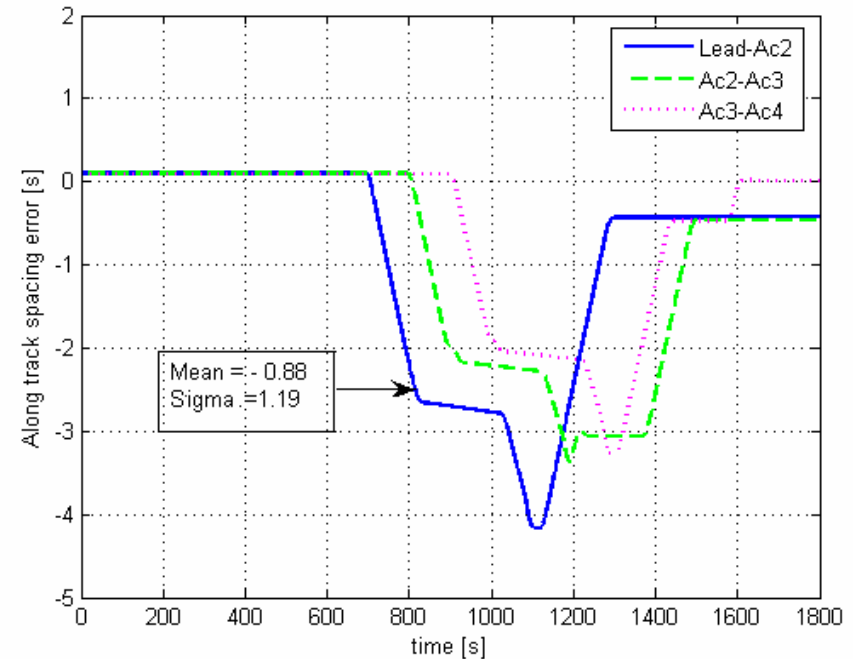
Demanded CAS – without lead history based prediction

Demanded CAS – with lead history based prediction

Results: sequence of 4 aircraft



Along track spacing errors
without lead history based prediction



Along track spacing errors
with lead history based prediction

Conclusion

- **Airborne spacing director**
 - Identified initial set of performance requirements and design constraints for 'merge behind' and 'remain behind'
 - Prototyped and tuned lead history based prediction algorithm for manual 'remain behind' to increase average interval between speed adjustments from ~1 minute to >3 minutes
 - Tested on sequence of four aircraft in manual 'remain behind'
- **Future work**
 - Extend the tool to 'merge behind' manual mode
 - Compare performance of manual and automatic modes
 - Test robustness for strong winds and turbulence
 - Refinement of requirements through real-time simulation