National Aeronautics and Space Administration

Terminal Area Procedures for Paired Runways

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A Joint Airspace Systems Program, Aviation Safety Program, and FAA Study

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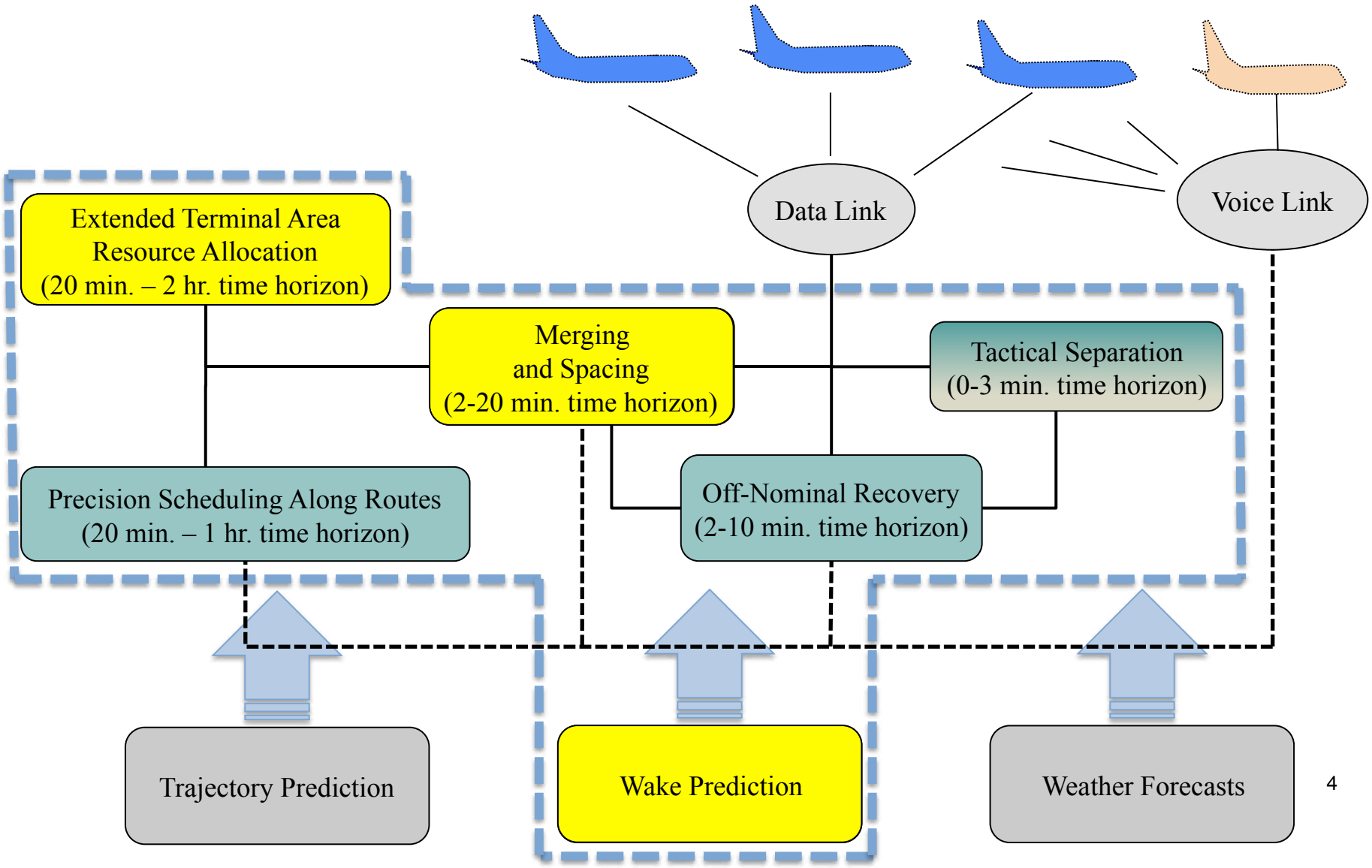
Objective

- To investigate integrated procedures for flight deck and air traffic control in the terminal area for simultaneous approaches
  - Levels of flight deck automation
  - Roles of the air traffic controller and the flight crew in pairing aircraft and monitoring their conformance

Motivation

- Significant efficiency and capacity are lost when poor weather conditions limit operations on parallel runways closer than 4300ft.
- The FAA would like to reduce runway separation from 4300ft to 2500ft and even to 750ft.
- NextGen has the goal to increase capacities under all weather conditions on airports with parallel runways <4300ft apart.
- Previous studies investigated roles of pilots and controllers separately, and examined aircraft that are already paired.
  - This study examines the integrated dynamic role of pilots and controllers, as well as procedures and tools for the actual pairing.

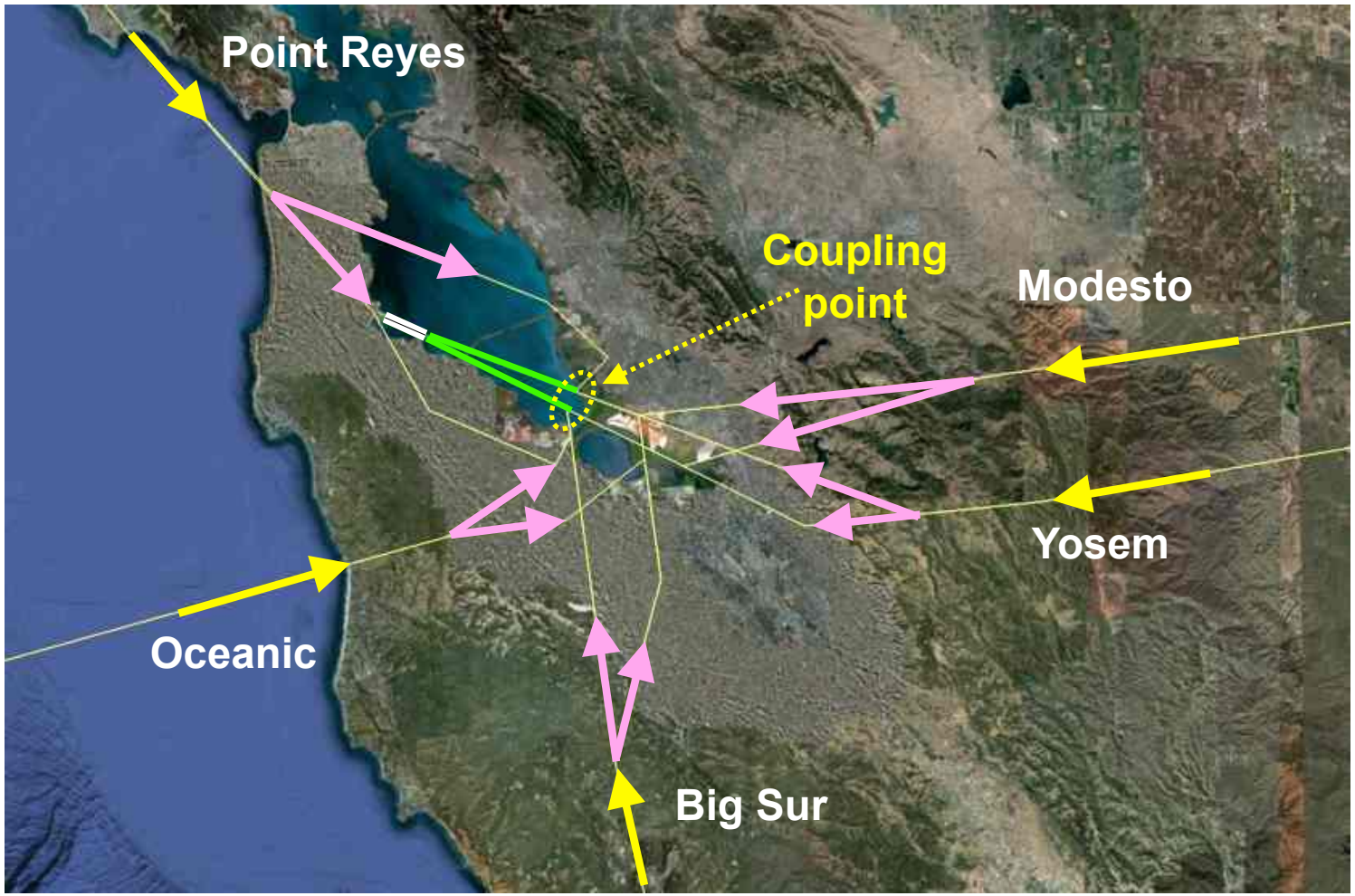
Very Closely-Spaced Parallel Runway Operations



Concept

- Technology assumed (Far Term 2025)
  - Differential Global Positioning System (DGPS)
  - Augmented Automatic Dependent Surveillance-Broadcast (ADS-B)
  - Augmented cockpit display
  - Required Navigation Performance (RNP) 1.11
- Aircraft are provided 4D trajectories and managed simultaneously to the coupling point, 12 nmi from threshold
  - Coupling point is when the automation of the two aircraft are sharing data and are linked to one another through the aircraft automation
- Maintain precise time separation of 5-25 s
- Speed adjustments only to meet Required Time of Arrival (RTA)

San Francisco Arrivals



Experimental Conditions: Flight Deck

- Functionality
  - Automation to auto-control aircraft speed and capture, then maintain, a pair
    - Future/Paired Dependent Spacing, or PDS)
  - FMS ETA information (current day)
- Displays for pairing conformance monitoring
  - Graphical display set 1: distance error relative to a desired position in the profile
  - Graphical display set 2: ETA prediction based upon current ground speed

Experimental Conditions: ATC

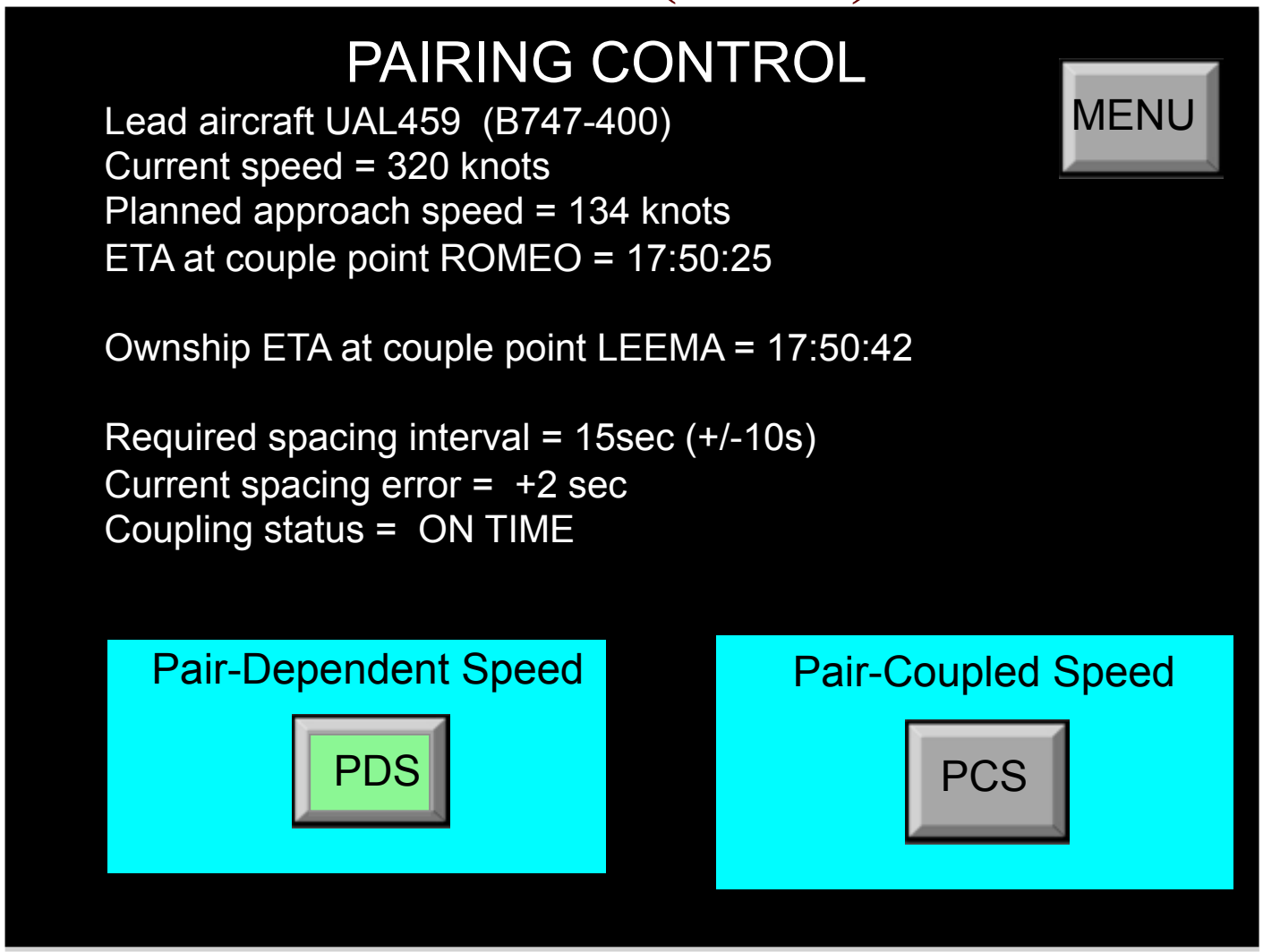
- Three positions (modified San Francisco Airspace): Niles, Boulder and Area Coordinator
- Ground side automation provides one optimal pairing solution (but controller can override at any time)
- An aircraft may be paired with an aircraft from any of the other 5 streams but not the same stream (to avoid overtake)
- Sector controllers are responsible for standard separation between pairs of aircraft (and singles)
  - Sector controllers are not responsible for aircraft spaced with less than standard separation (4-5 nmi before Coupling point to threshold)
- Sector controllers will control leader aircraft
  - Sector controllers will not try to space/control trailer aircraft normally, only by exception

Methods

- Human-in-the-loop simulation
- Conducted in June/July 2010
- SFO airspace used (modified for procedures)
- Our participants always flew in the trailing aircraft position
- Participants: 6 flight crews, 3 controller teams
- Advanced Concept Flight Simulator (ACFS) and ATC simulator
- Number of data collection runs
  - 9 runs per crew
  - 18 runs per controller team
- Training and practice scenarios for participants

Flight Crew Tools and Displays

SFD Pairing/Coupling Page when Future Automation (PDS) is Available



Display Set 1 (Conformance bars around the aircraft)

FMS annunciation after pairing

Primary Flight Display

Navigation Display

On-time window markers

Aircraft position indicator

On-time window

LSI

Display Set 1 (Conformance bars around the aircraft)

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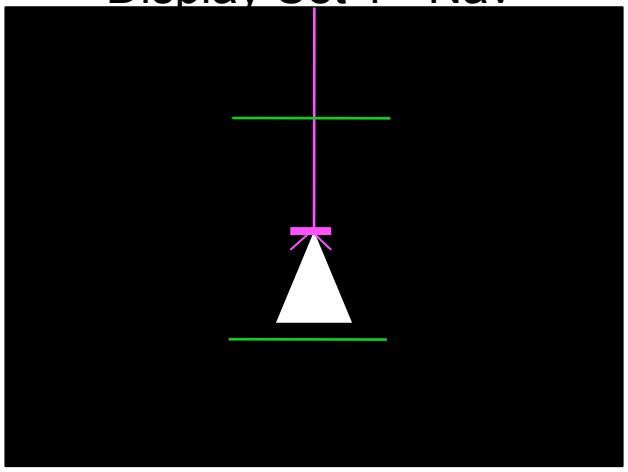
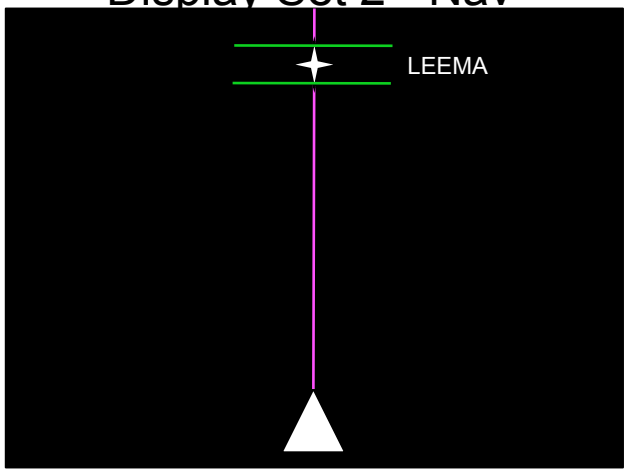
Display Sets 1 & 2: Conformance bars on the Navigation Display

Display Set 1 - Nav

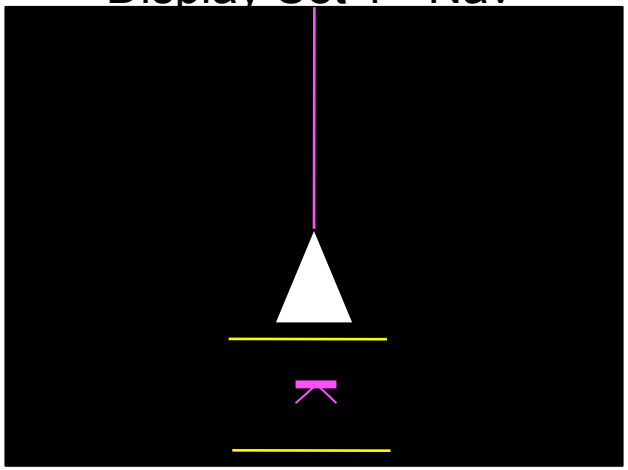


In conformance

Display Set 2 - Nav

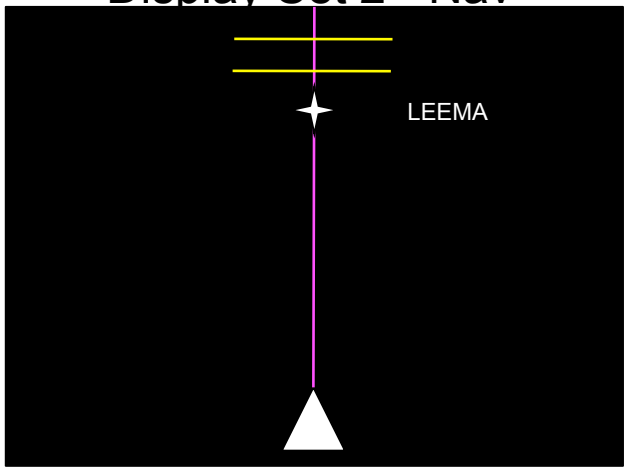


Display Set 1 - Nav



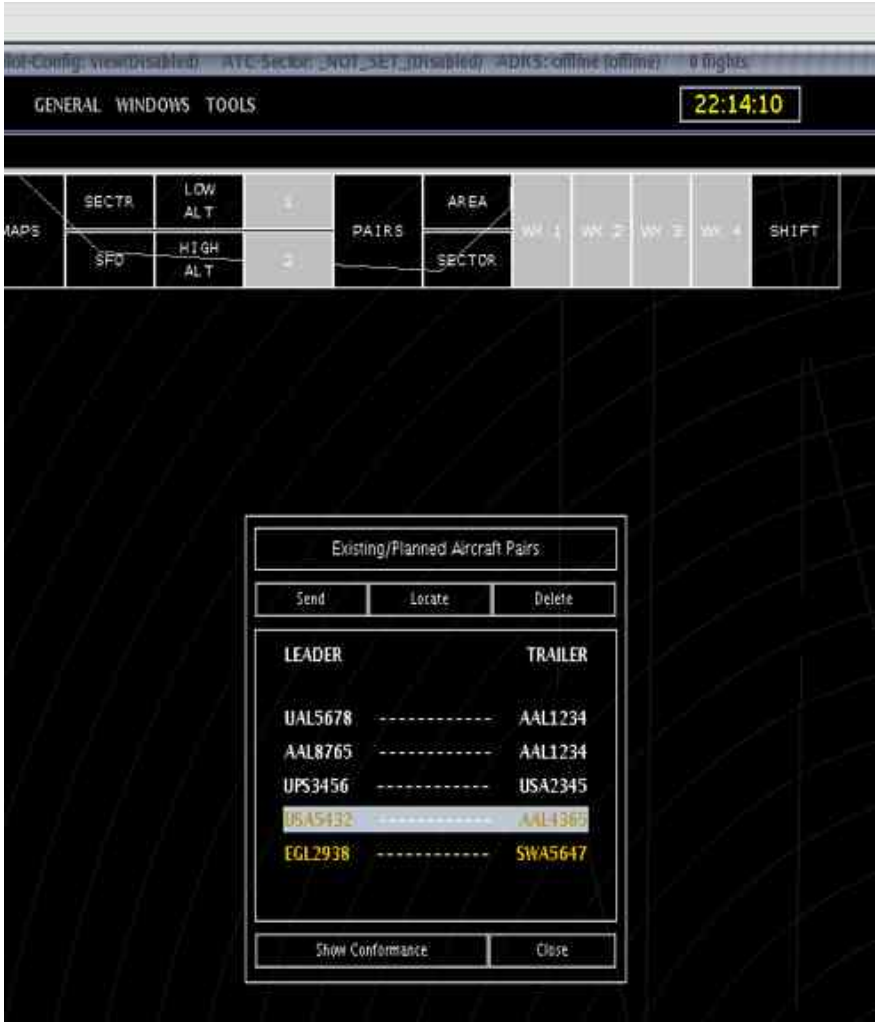
Out of conformance – early

Display Set 2 - Nav



Controller Tools and Displays

Area Coordinator – How to select pairs offered by automation?



Area Coordinator – How to select pairs offered by automation?

If pair is acceptable, highlight pair in table and press “send”

Aircraft pair turns amber and data link message is sent to both aircraft

Call signs of both aircraft turn green after acknowledge is received

Conformance Monitoring - Will the pair make the 15s temporal separation at coupling point?

Select “Show Conformance”

Conformance bars on the follower aircraft

If out of conformance, then aircraft pairing may be canceled

Preliminary Results

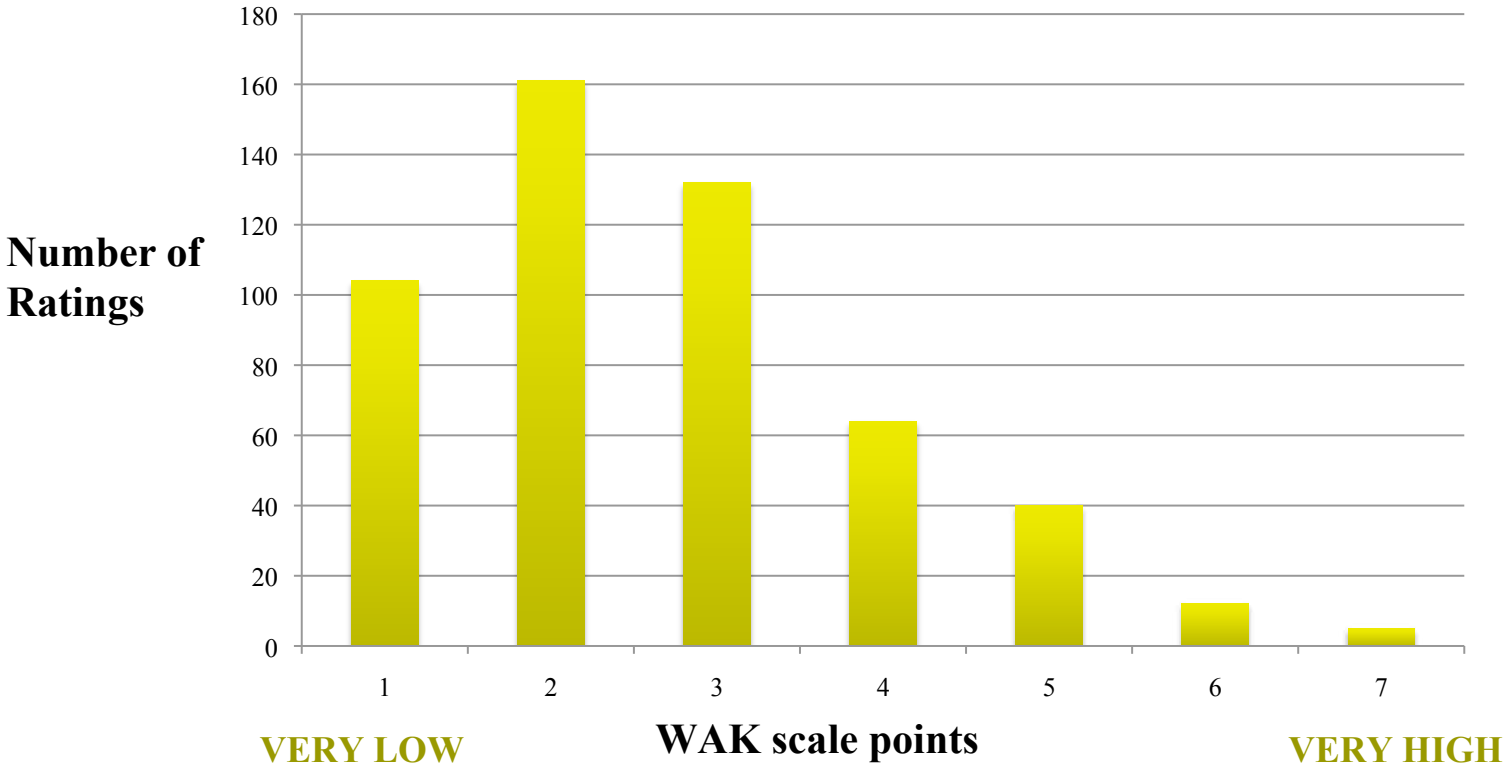
Preliminary Pilot Results

Pairing Performance for ACFS Crews (the trailing aircraft)

- The participant crews were able to successfully pair in all cases
- Our crews did not cancel any pairs
- There were no losses of separation

Pilot Workload

- Crews conducting pairing procedures indicated relatively low workload levels
  - Mean of about 3, with scale of 1-7



Pilot Situation Awareness

- Situation awareness measures revealed medium to high situation awareness for pilots across all variables examined in this study
  - There were no significant differences for automation levels or conformance monitoring display types

Pilot Questionnaire Data

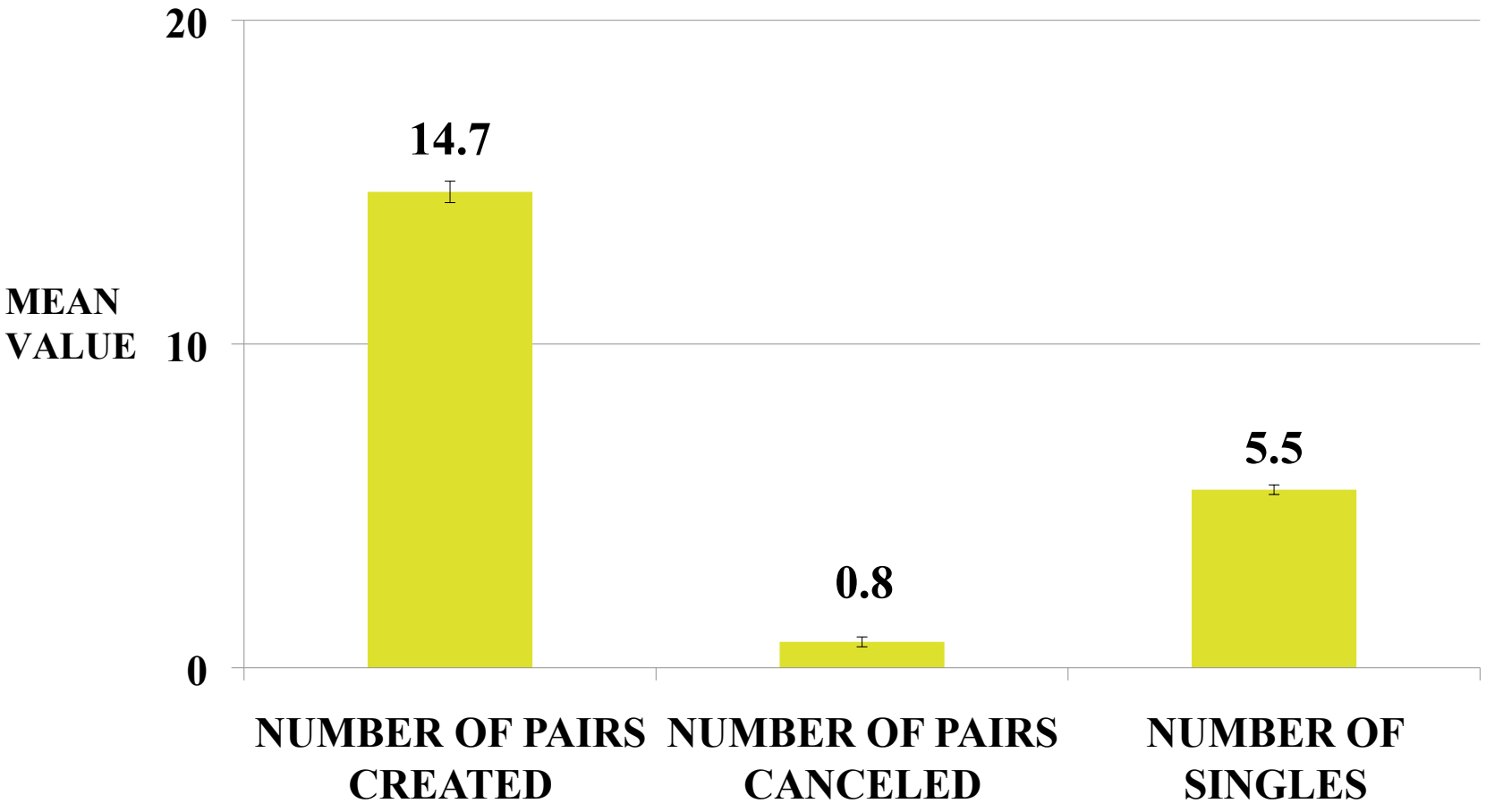
- Procedures were feasible and safe
- Display 1 (current state) v. Display 2 (predictive data)
  - Crews felt that were more accurate with Display 1
- Display 2, which used predictive data, was confusing to interpret
  - Predictive data caused display features to change too rapidly
- Infrequency of use of the procedures may lead to problems with training and implementation

Preliminary Controller Results

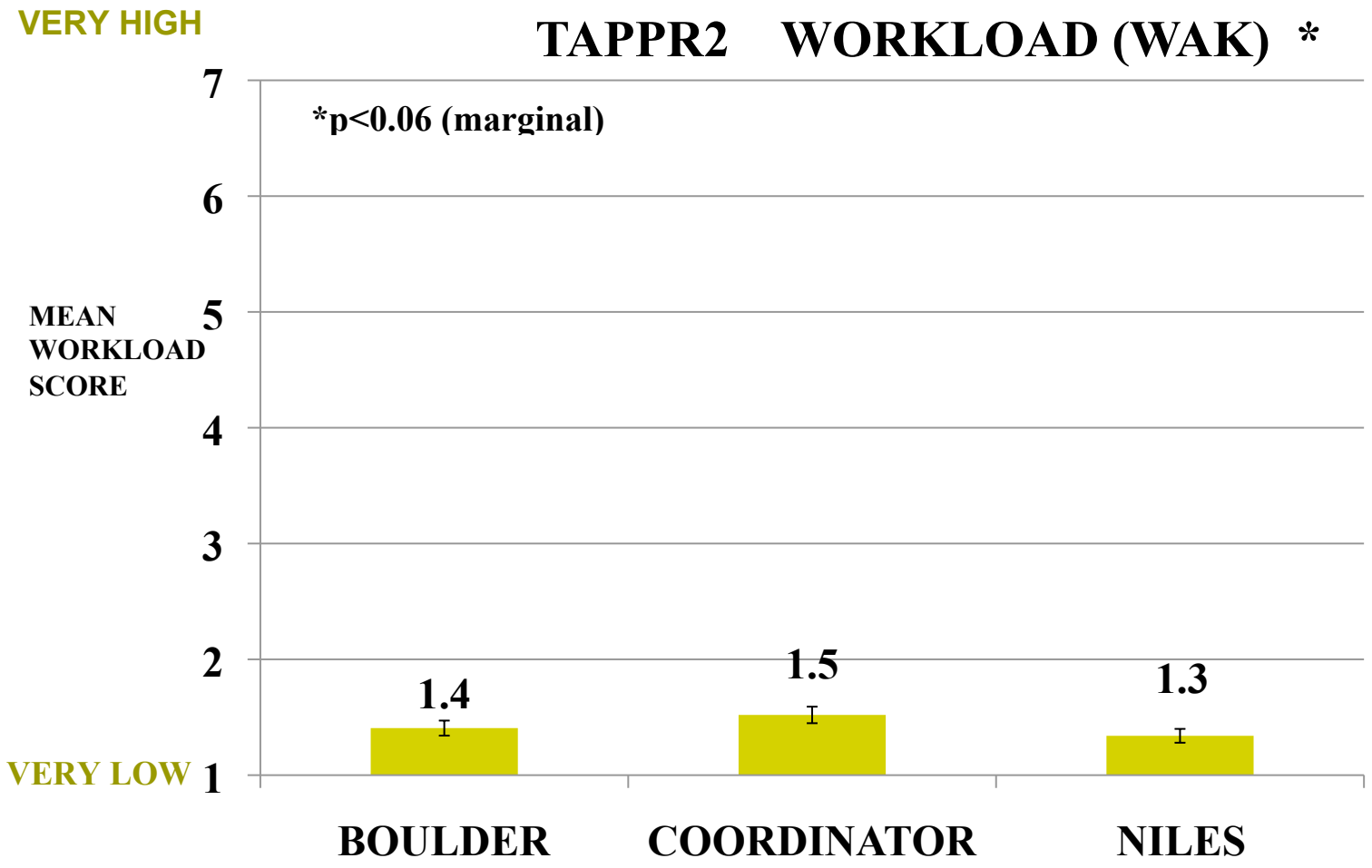
Pairing Performance for Controllers

- Controllers were able to successfully pair our ACFS simulator all cases
- There were no losses of separation

Pairing Performance for Controllers (Per Run)



Controller Workload (by position)



Controller Situation Awareness

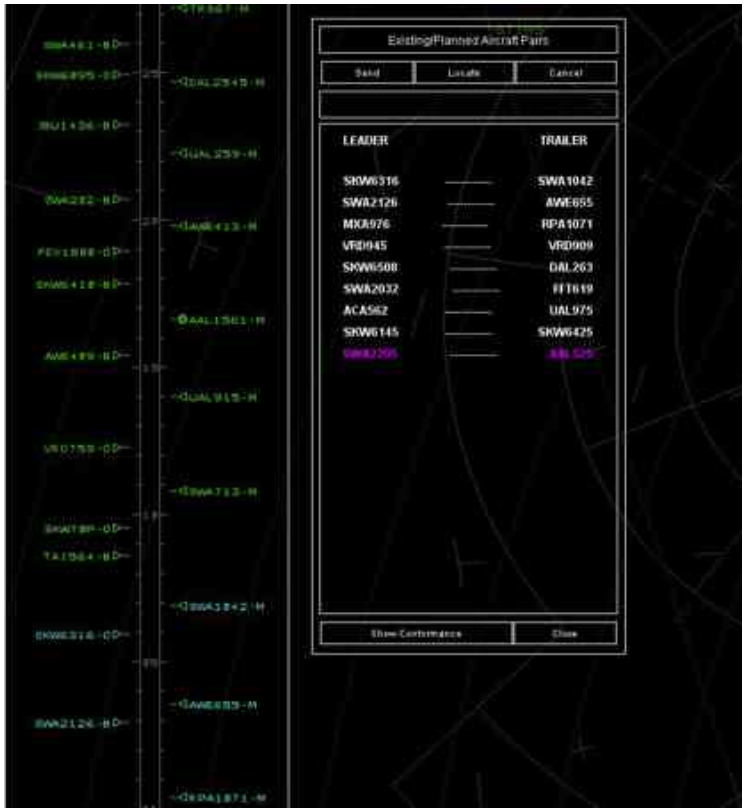
- Situation awareness measures revealed medium to high situation awareness for controllers
  - There were no significant differences among the three controller positions for situation awareness

Technology Transfer
Simultaneous Offset Instrument Approach (SOIA)

- Simultaneous Offset Instrument Approach (SOIA) demonstration by NASA for the FAA (April 2011)

- Objective: To reduce the cloud ceiling from 2100 ft to 1600 ft by providing the controllers with tools to help with set up the simultaneous approaches

- Technology transfer includes use of pairing and conformance monitoring tools from TAPPR



Possible Future Work

- Information requirements necessary for pilots and controllers when conducting pairing operations for parallel runways
- Roles of the users and automation
- Determine the conditions that may cause pairing cancellation
- Impact of cancellations on arrival procedures
- Impact of off-nominals

Back Up Slides

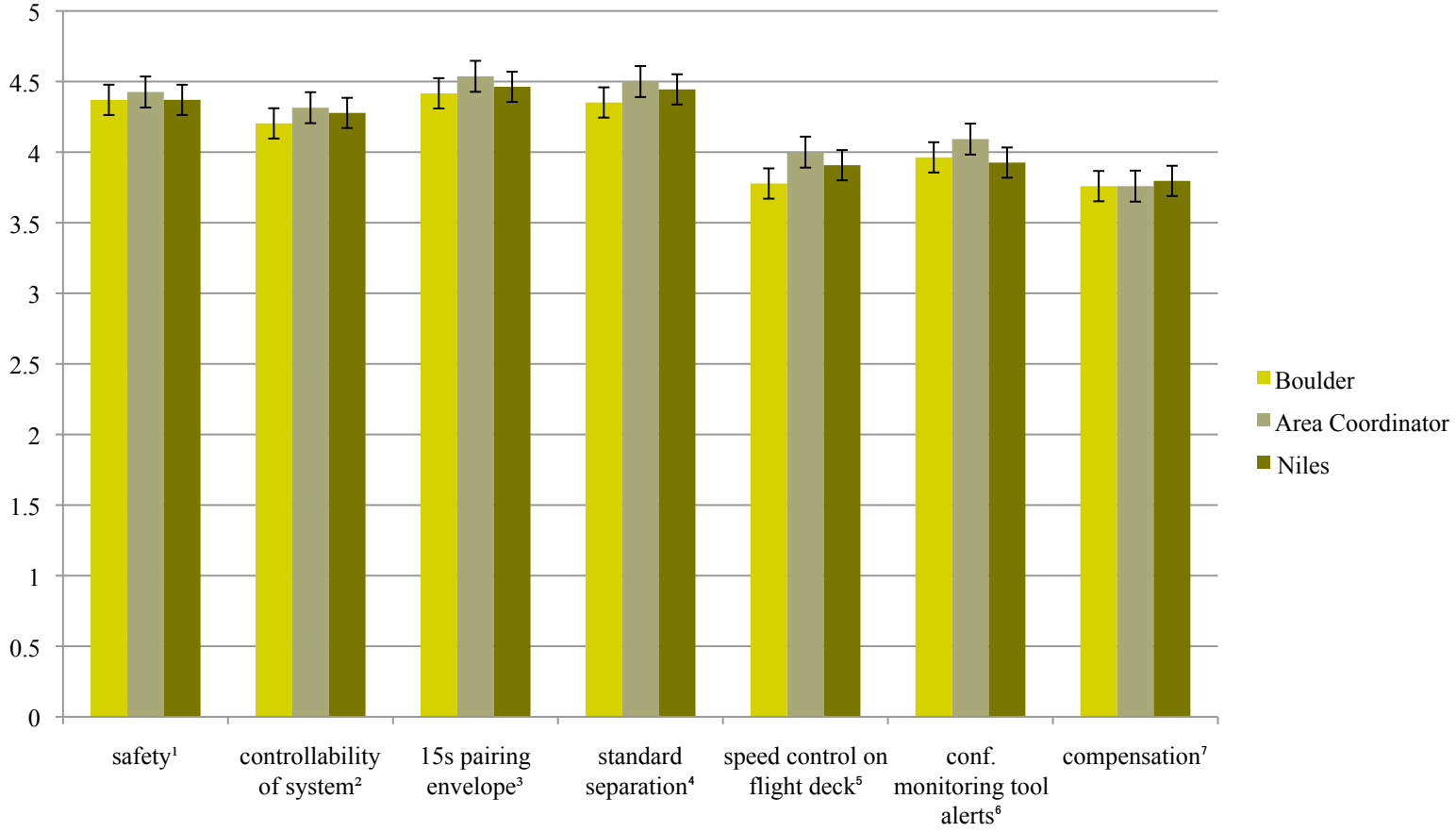
Operations

- Aircraft may be paired from any of the five arrival streams.
- Two consecutive aircraft from the same stream may not be paired.
- The TRACON boundary will be the freeze horizon for the pairing algorithm / automation.
- An aircraft is not allowed to overtake another aircraft in the same stream
- All adjustments to flight trajectories to meet ETAs will be made by speed adjustment only, not path stretching or shortening.
- Paired aircraft must arrive at the coupling point with the trailer between 5 and 25 seconds behind the leader.
  - 5-25 second spacing parameter is based upon avoidance of wake

Additional Pilot Feedback

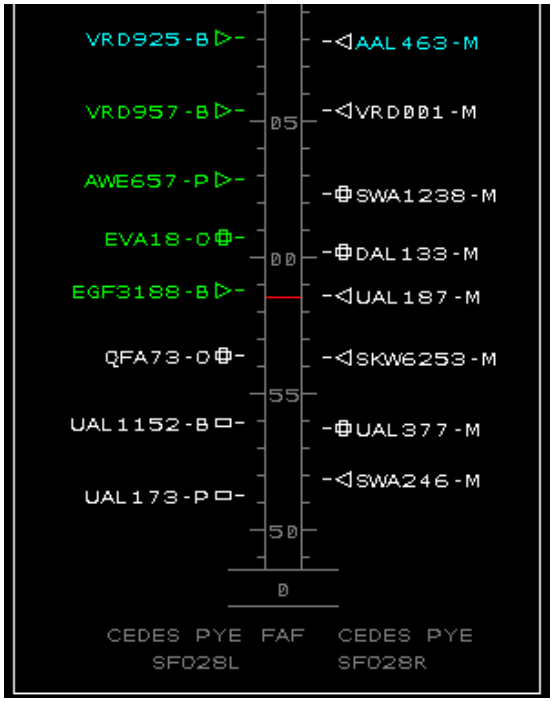
- Additional Flight Deck Information Requested
  - Countdown of number of miles to coupling point
  - Trend line
  - Lead aircraft's altitude
  - Lead aircraft's flight path
  - Recommended speed bug

Controller Questionnaire Data



Area Coordinator- how to select pairs?

- 5 seconds after both acknowledgements are received, the color of the pair in the pair-table changes to white, indicating the pair is finalized
- The finalized pair is now displayed to all controllers in their respective pair-tables
- The finalized pair also turns blue/ cyan on the timeline.



When to delete a Pair?

- If the aircraft seems to go out of conformance, which leads to the alerts showing the aircraft is early (pink) or late (blue) in the pairs table.

OR

- If the trailing aircraft needs speed adjustments that cannot be made while flight deck automation is engaged.

OR

- If the pilot calls in saying “Unable to maintain pair due to …”