Air and Ground Simulation of Terminal-Area FMS Arrivals with Airborne Spacing and Merging

Todd J. Callantine, Paul U. Lee, Joey Mercer, Thomas Prevôt

San Jose State University/NASA Ames Research Center

Everett Palmer

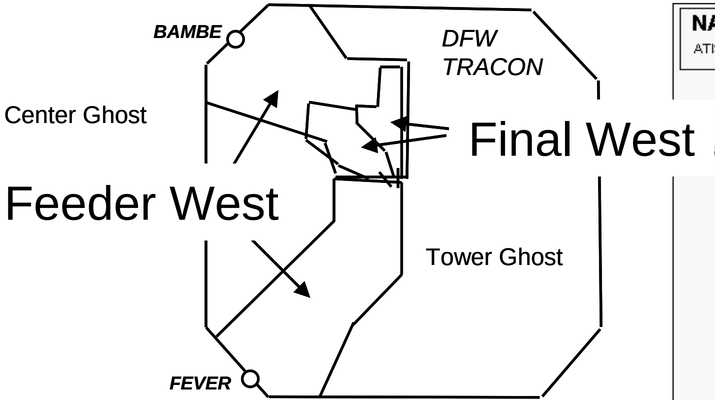
NASA Ames Research Center

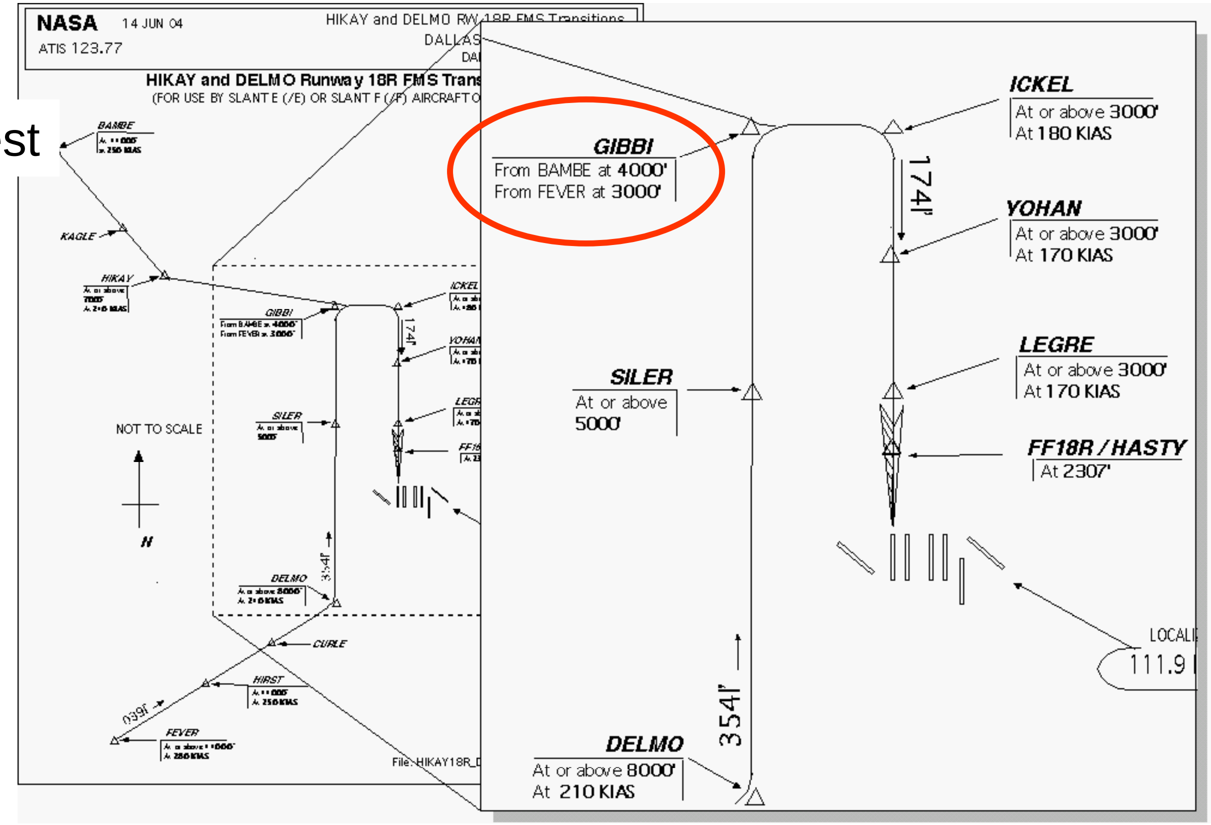
NASA Airspace Systems Program
Advanced Air Transportation Technologies Project
Distributed Air-Ground Traffic Management Element

Introduction

- **Distributed Air Ground Traffic Management (DAG-TM) project research**
  - Conducted at NASA Ames, Glenn, and Langley Research Centers to investigate feasibility and benefits of redistributing practitioner roles and responsibilities for 2015 time frame
  - En route studies: trajectory negotiation using advanced data link and controller tools, delegation of separation responsibility to flight crews
  - Trajectory-based arrival metering with well-integrated controller tools could improve meter fix arrival accuracy and produce more efficient, predictable, and evenly spaced flows into the TRACON
- **Concept Element 11 (CE11): Terminal Arrival: Self-Spacing for Merging and In-trail Separation—NASA Ames Air and Ground Simulation**
  - Airspace Operations Laboratory (AOL) and Flight Deck Display Research Laboratory (FDDRL) DAG-TM simulation infrastructure
  - TRACON FMS routes linked to en route FMS arrivals
  - Traffic scenarios included coordinated flows of aircraft arriving as if metered using DAG-TM en route concepts
  - Envisioned controller strategy: use tools to adjust aircraft toward scheduled time-of-arrival (STA) at their assigned runway, issue spacing or merging clearances to 'lock in' sequence and temporal spacing
  - Controllers responsible for safe separation, all clearances by voice

Airspace, Scenarios, and Participants





- NW and SW arrival flows, some NW flow aircraft assigned to 13R (vacated slots filled by SW arrivals to 18R)
- End of flows uncoordinated
- Subjects
  - 4 professional TRACON controllers (15-20 years experience), 9 commercial pilots
- Confederates
  - 4 retired controllers, 6 general aviation pilots
- Two 'Feeder-Final' subject controller teams in 'parallel worlds,' rotated daily

Experimental Conditions

Flight Deck Decision Support Tools

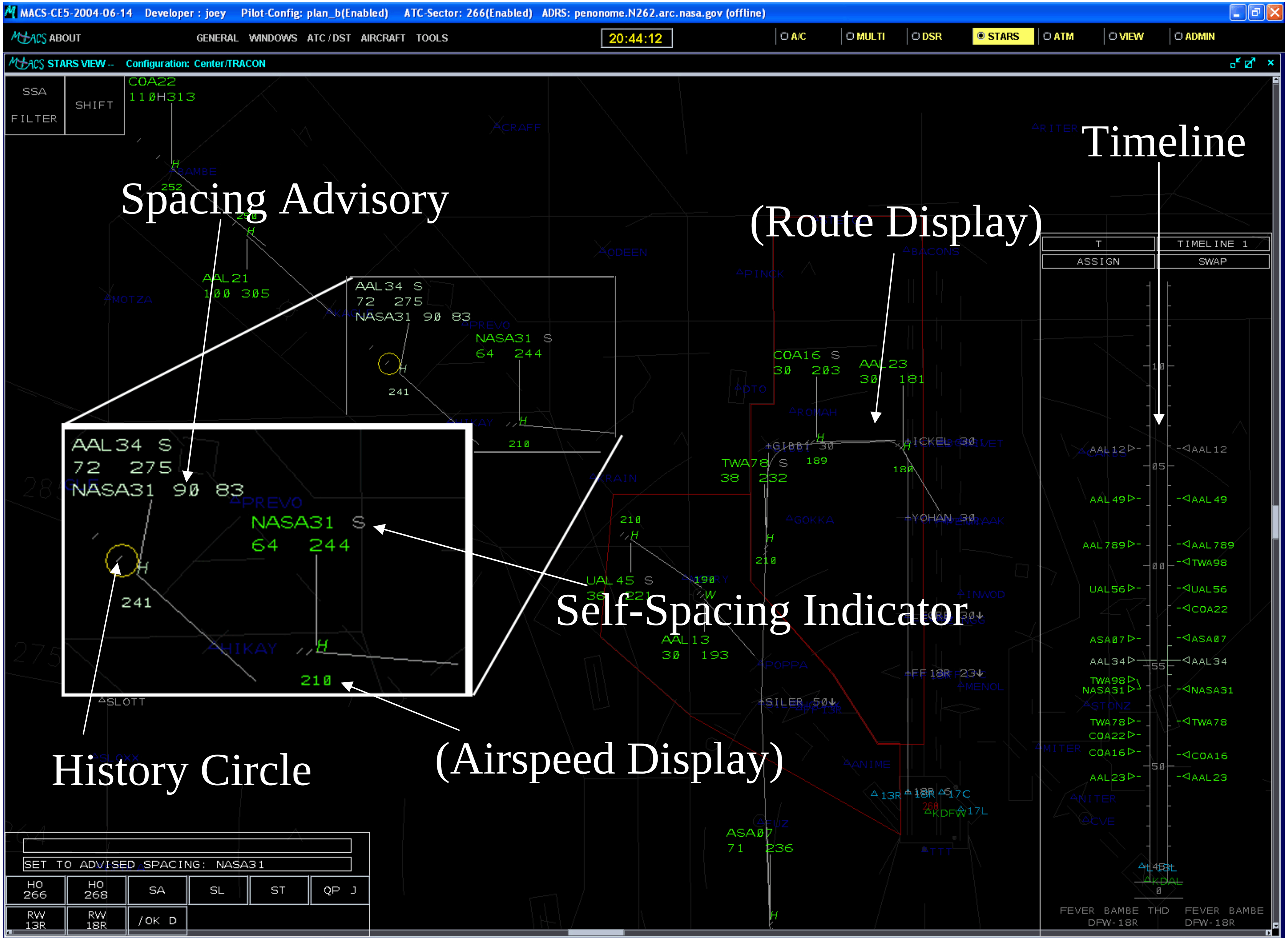
Controller Decision Support Tools	*YES*	*NO*
YES	**Air & Ground Tools** 75% spacing-equipped aircraft* Spacing/merging clearances available for equipped aircraft Controller tools to monitor temporal spacing	**Ground Tools** No equipped aircraft Controller tools to monitor temporal spacing
NO	**Air Tools** 75% spacing-equipped aircraft* Spacing/merging clearances available for equipped aircraft	**No Tools** No equipped aircraft

ALL aircraft ADS-B and FMS-equipped

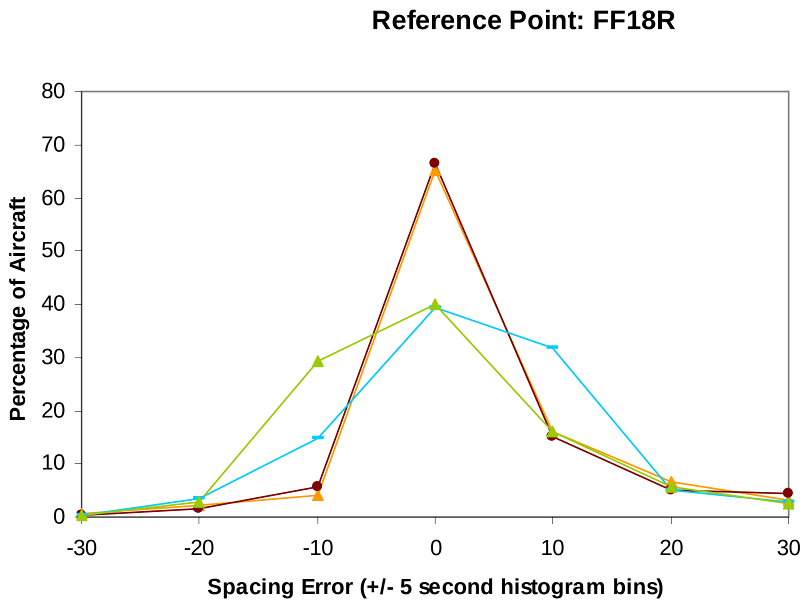
- Two week study in August 2004, two training days, one debriefing day
- First aircraft ‘untouchable’
- Randomized conditions, one pair of 35 minute trials in each condition per day, Feeder and Final swapped positions after the first trial in each condition

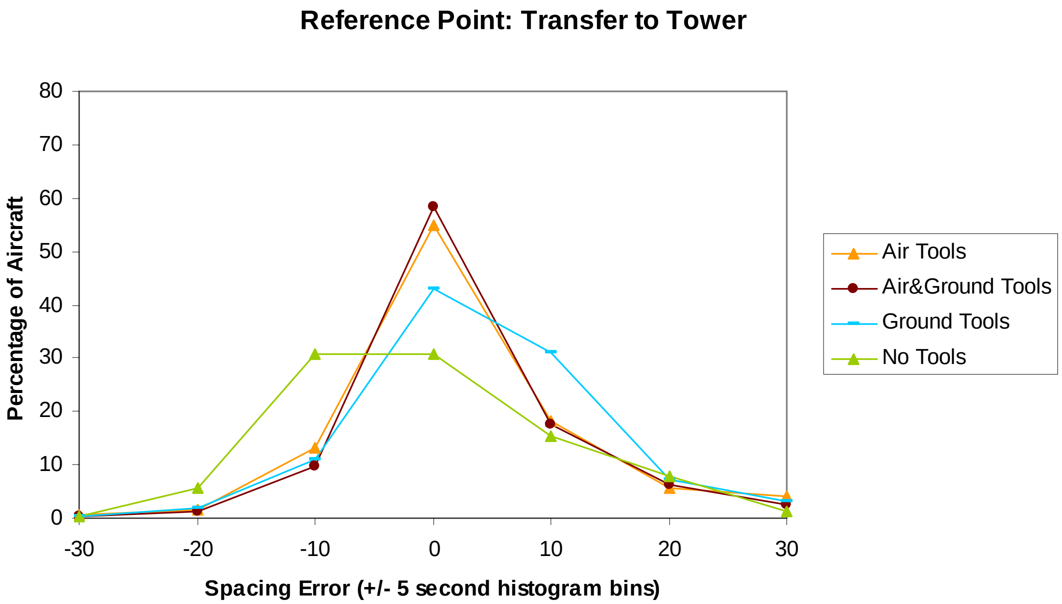
* CDTI-equipped piloted simulators and pseudo-aircraft assigned to primary landing runway (18R)—also mixed *spacing guidance*

Enhanced MACS STARS Display



Spacing Accuracy

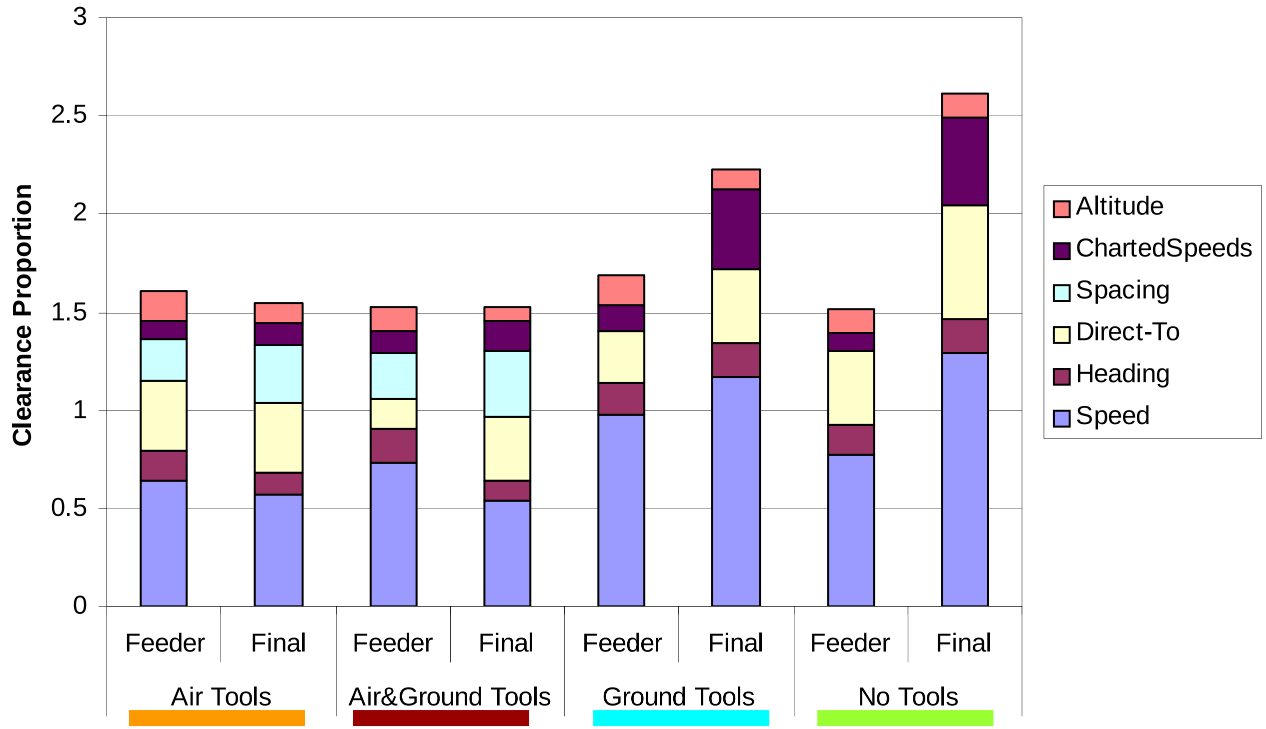




- Airborne spacing capabilities improved temporal spacing accuracy
- Ground tools alone did not further improve accuracy, but did help controllers err on the conservative side
  - Improved spacing awareness may help minimize go-arounds
- 'Transfer to tower' metrics suggest ground tools improve spacing accuracy
- Airborne spacing appears to have helped aircraft maintain required spacing during Tower Ghost ownership

Maneuver Clearances*

- Spacing clearance phraseology caused *no* confusion
  - “American 123, follow United 345 80 seconds in trail”
  - “United 345, merge behind and follow American 456 80 seconds in trail”

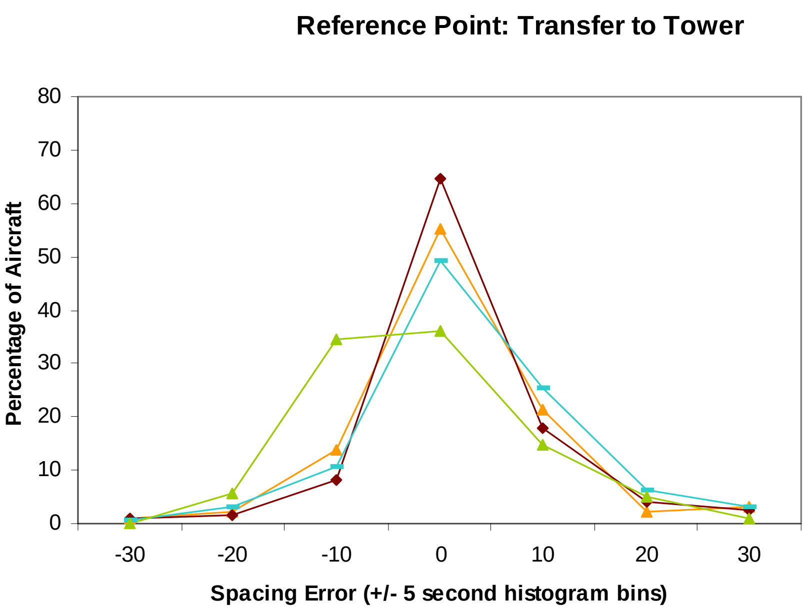


- Airborne spacing results in fewer clearances per aircraft, particularly for the Final controller.
- Spacing clearances tend to supplant speed clearances and associated ‘resume charted speeds’ clearances.

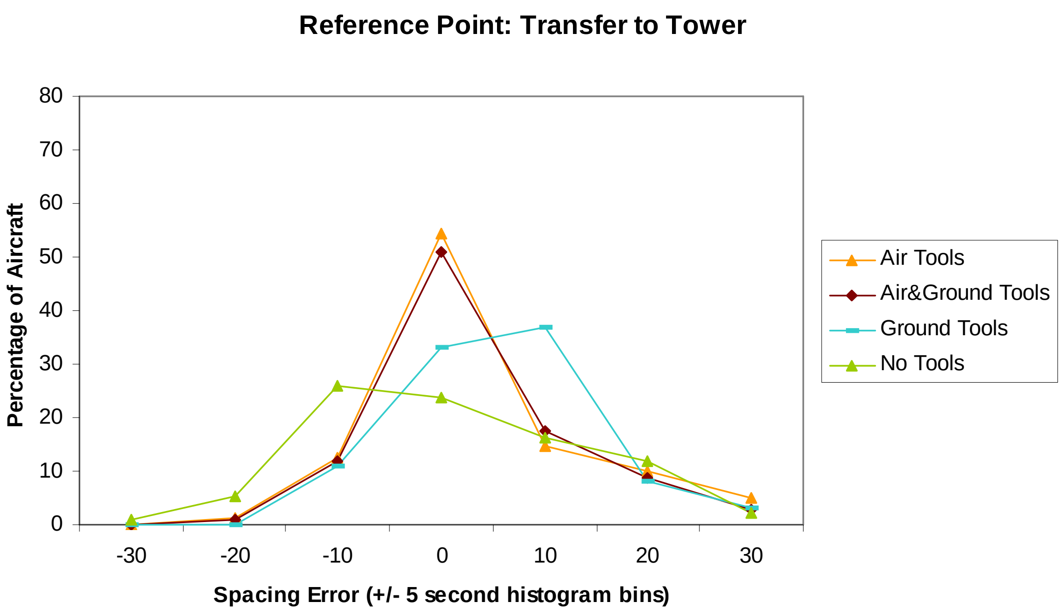
* Preliminary data inferred from MACS pilot logs

Flow Coordination: Spacing Accuracy Effects

Coordinated Flows

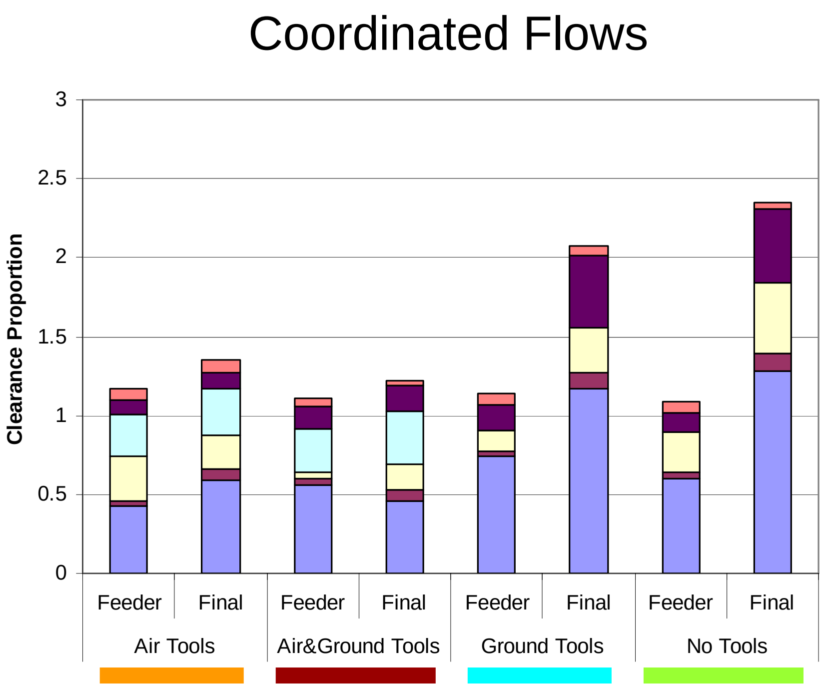


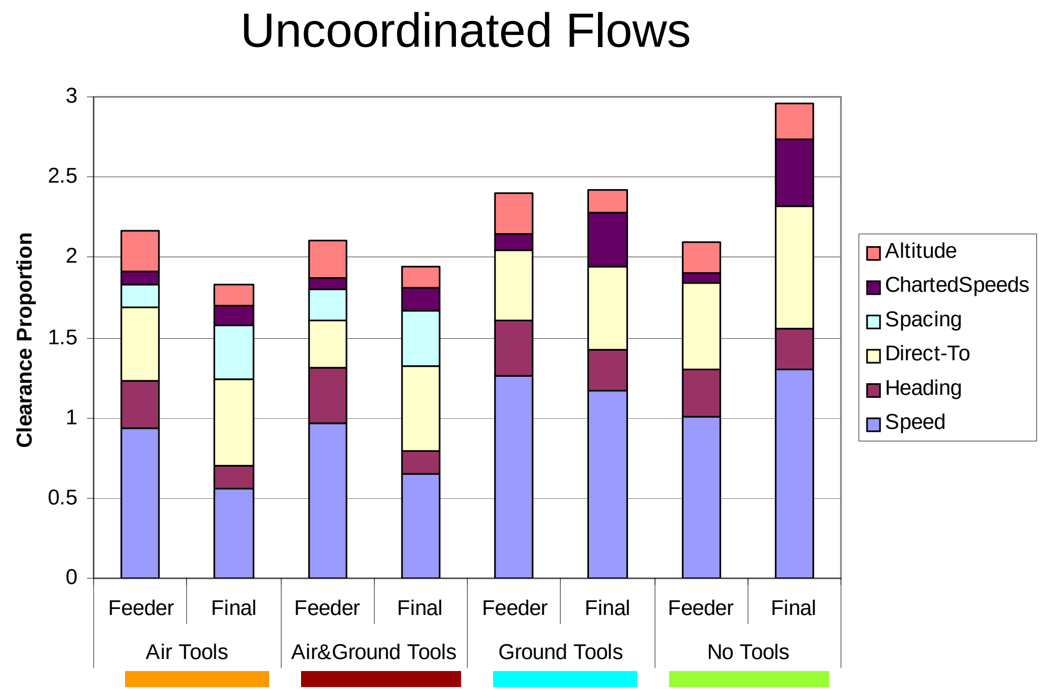
Uncoordinated Flows



- For *uncoordinated* flows:
  - Airborne spacing capabilities improved temporal spacing accuracy
  - Ground tools produced more conservative spacing
  - No Tools yielded broad variation in spacing accuracy

Flow Coordination: Maneuver Clearances

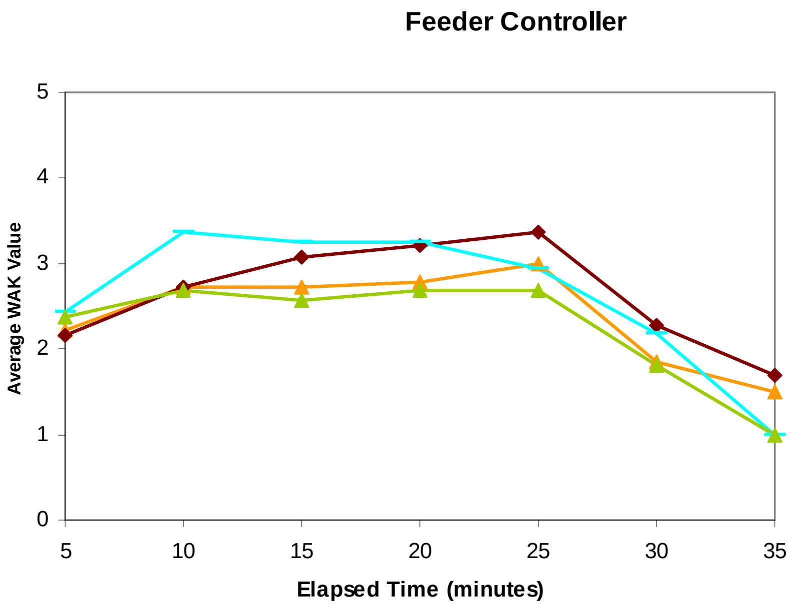


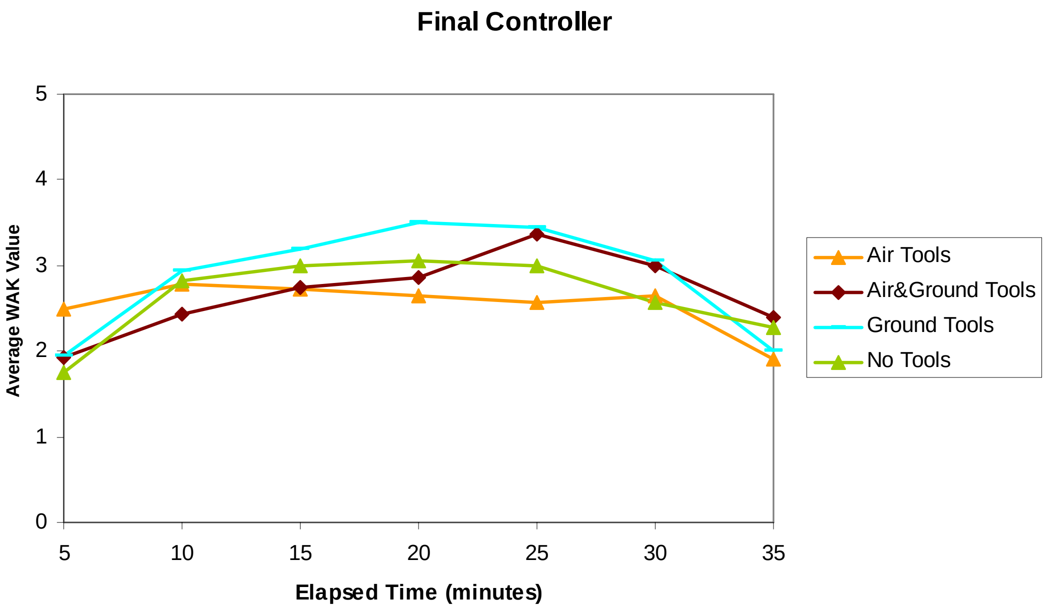


- For *coordinated* flows:
  - In spacing conditions, spacing clearances comprised a greater proportion of the clearances issued
  - Feeder and Final issued fewer clearances per aircraft and used smaller proportions of heading vectors and temporary altitudes likely to disrupt FMS operations
  - In conditions *without* airborne spacing, disparity in number of clearances issued by Final and Feeder is greater than for uncoordinated flows

Average WAK Scores

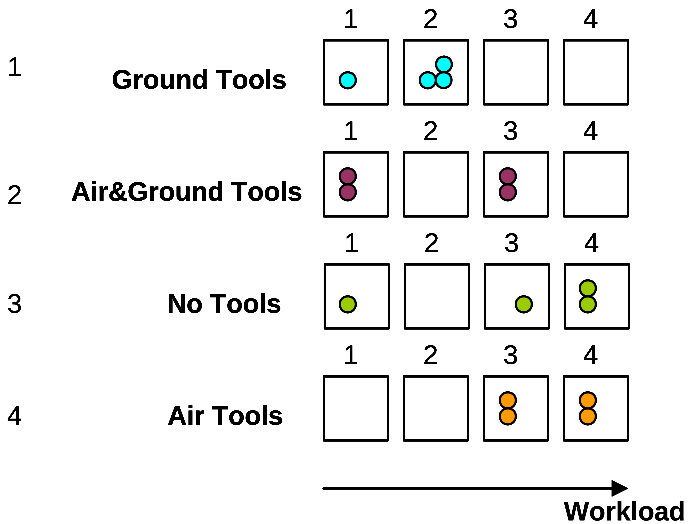
- Scale = 1 (lowest workload) to 7 (highest), Assessment interval = 5 minutes

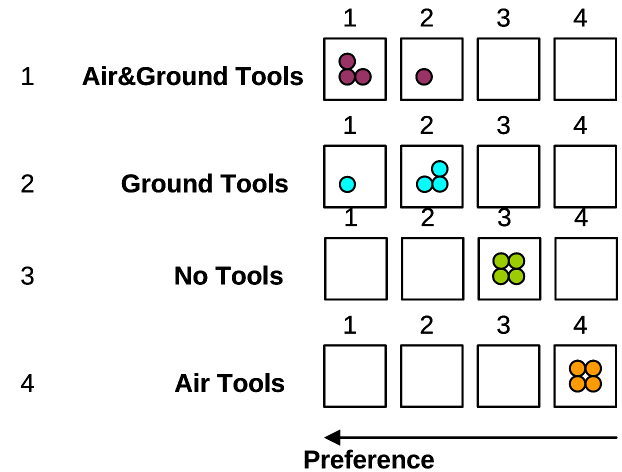


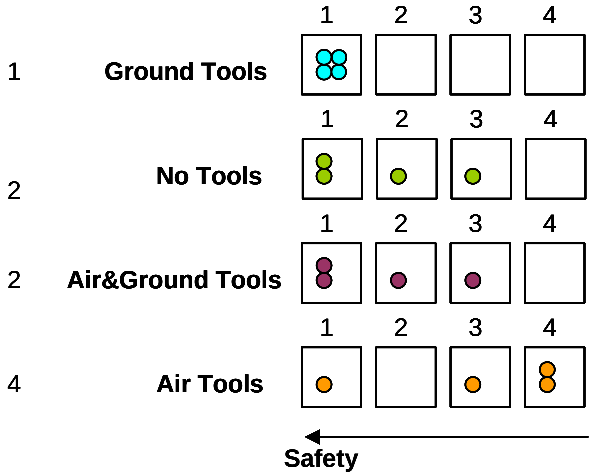


- Workload remains within acceptable range

Some Post- Questionnaire Results







* One controller described all conditions as equally safe

- Workload rankings do not reflect WAK scores
  - Perceived workload increase from maintaining separation responsibility?
- Safety rankings similar to workload
  - Effect of any unpredictable spacing behavior?
- Controllers *preferred* more information
  - Similar to workload rankings

Conclusion

- Concept is feasible and improves spacing accuracy
- Controller workload remained within an acceptable range
- Terminal-area airborne spacing works best when linked to en route concepts capable of delivering aircraft in coordinated flows.
- Results present a conservative view of benefits achievable with a mature, fielded version of the concept

- Areas for further analyses and research:
  - Spacing guidance
  - Effects of unequipped aircraft
  - Heavier traffic, with reduced or dynamic separation minimums
  - En route and tower controller participants
  - More realistic Feeder controller positions