Evaluation of an Airborne Spacing Concept to Support Continuous Descent Arrival Operations

Jennifer L. Murdoch, Bryan E. Barmore, Brian T. Baxley
NASA Langley Research Center, Hampton, VA

Terence S. Abbott
Booz Allen Hamilton, McLean, VA

William R. Capron
Lockheed Martin, Hampton, VA
Why CDA?

Continuous Descent Arrivals, aka Optimal Profile Descents, offer improvements in fuel efficiency, flight time and noise reduction.

The freedom to optimize each aircraft reduces the controller’s ability to manage the aircraft.

Additional spacing is often added to protect against this variability.

This limits their usefulness to low-demand environments.
Airborne spacing makes use of airborne surveillance, ADS-B In, to allow the aircraft to manage their spacing relative to another. The aircraft can make small speed variations to stay close to their optimal profile while meeting the controller’s spacing goal.

Can this be done efficiently?
Merging and Spacing Working Group

- Started in 2005
- Sponsored by FAA, includes MITRE, NASA, UPS, others
- Develop scheduling and airborne guidance tools to provide efficient flow and flights
- Focus on high-demand, medium-complexity airport

Current implementation is being tested at SDF

- Unidirectional flow using one arrival route
- Limited number of equipped aircraft and trained crews
- Airline-based sequencing and scheduling

Future implementation

- Several arrival routes to multiple runways
- Dependent parallel arrivals
- ATC-based sequencing and scheduling
NASA’s Airborne Precision Spacing

NASA Langley has been developing and testing a trajectory-based spacing concept and prototype tool for several years.

Previous batch and human-in-the-loop simulations have shown a delivery precision of 2-5 seconds (standard deviation) at the runway threshold.

Spacing tool needs to know assigned route and planned final approach speed for both aircraft.

An on-condition ADS-B report provides this information.

Trajectory-based approach allows spacing to begin well before aircraft are in trail.
Merging and Spacing Evaluation

The goal was to study the trajectory-based spacing tool in an initial M&S environment under normal and off-nominal ATC events.

The off-nominal ATC events include:
- Vectoring during descent
- Speed intervention
- Large spacing error at initial set-up
Experiment Objectives

Determine completeness and acceptability of pilot procedures
  Questionnaires provided after each run
  Workload measured with MCH rating scale
Evaluate use of pilot procedures
  Missed or incorrect steps
  Undesirable aircraft maneuvers
Evaluate the spacing performance
  Delivery accuracy and precision
  Fuel and time impact
Experiment Design

8 “crews” per scenario
8 scenarios per group
3 groups
192 data points

7 PC-based, single pilot workstation simulators
1 full-workload, two-crew, fixed-based simulator

Same aircraft type – narrow body, twin engine transport
Simulators

Integration Flight Deck (IFD)
- Full workload simulator
- Two crew members
- Out-the-window visuals

Aircraft Simulator for Traffic Operations Research (ASTOR)
- PC-based, mouse-driven simulator
- Single crew member interface
- Interface and displays based on modern Boeing glass cockpit
Participants

26 active commercial pilots from major US air carriers.
Average age: 48 ± 6 yrs
Average experience: 18.7 ± 7.8 yrs
22 B-777; 7 B-767; 2 B-747; 1 B-737

2 retired controllers worked en route and approach control as confederates
  Provided clearances and hand-offs
  Familiar with the Merging and Spacing operations
Scenarios

All A/C direct ENL or PRINC T/D just before PRINC #1 and #6 flies standard CDA
Gap between #5 and #6
ATC vector for one aircraft at either FL240 or FL180; 5 nm off-path
ATC speed intervene at FL180; resume before CBSKT

Nominal conditions:
50% wind forecast error
initial spacing deviation ±30 s
35-50 min flight time
Example Scenario

#1 - CDA

#2 – speed intervene

#3 – nominal spacing

#4 – nominal spacing

#5 – nominal spacing

#6 – bad initial spacing

#7 – ATC vector

#8 – lead was vectored
Nominal Procedure

1. Enter **Lead AC ID** and **Spacing Interval** (from company, not ATC) through MCDU page
2. Verify or enter ownship final approach speed
3. When valid guidance is presented, open the speed window on the MCP and enter the displayed speed
4. Monitor PDS speed and make adjustments when new speed is guided including configuration changes
5. When checking-in on a new frequency, add “company spacing”
   
   *Louisville Approach, NA891, …, company spacing*
Procedures and Operations Feedback

All completeness and acceptability questions answered on a 7 point rating scale.

Mean MCH* workload rating of 1.87 (SD = 0.78, N = 207) indicated that instructed tasks were easy/desirable, mental effort was low, and desired performance was attainable.

(* 10 point rating scale)
Completeness and Correctness

65% of pilots said they had a complete set of procedures for the situations they encountered (94% reported no problems).

9 said “no,” primarily citing minor issues:
- 1 problem was an experiment procedure, not flight procedure
- 3 formatting suggestions were provided
- 1 instance of confusion with wording
- 1 comment that a one-step procedure was not on the card
- 1 disagreement with the resuming criteria
- 1 pilot said he was unclear which speed to fly when terminating
- 1 pilot was uncertain as to when the EXCESS SPC ERR procedure should be used

Only minor anomalies associated with the spacing procedures were detected.

Variations on the phraseology
Spacing Performance

Designed for 138 spacing operations; 19 were not completed due to the off-nominal ATC events.
Location of Speed Changes

Profile speed changes / average per segment

Average of 6 additional commands
Max of 12 additional commands
More fuel burn for speed intervene (VNAV SPD and spacing) than VNAV PTH.
Conclusions

Airborne spacing along Continuous Descent Arrivals was shown to be feasible and beneficial. Pilots felt the procedures were complete, usable and could be incorporated into their other tasks. Aircraft were delivered within ±5 seconds (1100 ft) with few outliers. Approximately 6 additional speed adjustments were needed for spacing. Airborne spacing had no impact on fuel burn or flight time.
Stability of operation

No statistical dependence on location in the arrival flow