Experimental Study of Cockpit Displays of Traffic Information for Pilot Self-Spacing in Congested Airspace

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ABSTRACT
An experimental study examined cockpit displays of traffic information for pilot self-spacing in congested airspace. Results demonstrate that pilots have the capability to benefit from additional traffic information and take over some additional control responsibility. Additionally, this experiment shows that pilots benefit from the presentation of velocity and closure rate, and from range spacing arcs.

Keywords
Cockpit display of traffic information, air traffic control

INTRODUCTION
Airport capacity often does not meet demand during peak operating periods, causing costly delays in addition to increasing air traffic controller workload. One concept to reduce controller workload and increase airport efficiency is to transfer some control of aircraft spacing to pilots. Several studies have examined potential applications of Cockpit Displays of Traffic Information (CDTI) that would facilitate this process [e.g. 1, 2].

This study examines the effects of three CDTI designs on pilot performance and workload, with specific focus on the amount and presentation of information pilots will need about the other aircraft. The specific task that pilots were asked to perform was to acquire and maintain spacing along an arrival behind another aircraft.

METHODOLOGY
Twelve pilots conducted a total of 144 standard terminal arrivals to a controlled airport in a Boeing 747-400 simulator. Each pilot flew four flights with each of the three CDTIs. An air traffic controller directed the spacing to create behind the aircraft in front of them. While the experiment also investigated different arrival procedures, this paper focuses on the different CDTIs that were tested.

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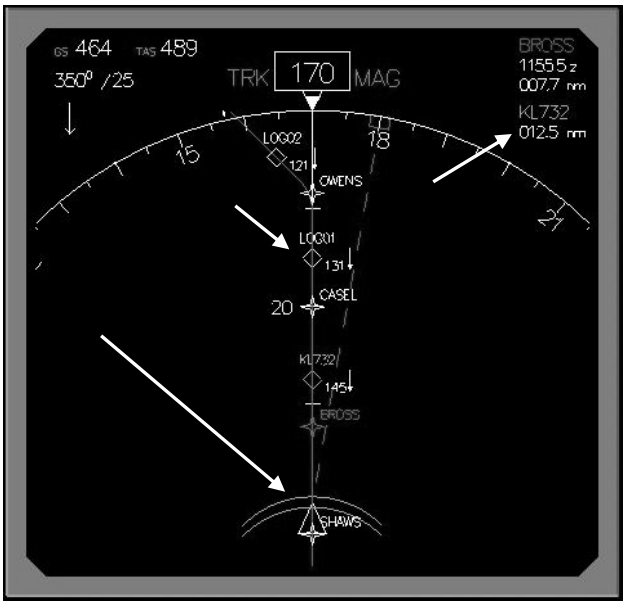

Figure 1: Display 1, Presenting Position of the Other Aircraft

Display 1, shown in Figure 1, displays the position of traffic. Aircraft horizontal position is shown with a diamond; relative altitude and transponder code are shown beside the aircraft symbol. The distance to the lead aircraft is shown textually in the upper right of the display. An arc can be set by the pilot at the spacing commanded by the controller as a reference. This display therefore emphasizes information about the position of traffic, shown in both spatial and textual format.

Display 2, shown in Figure 2, provides additional information in the form of the lead aircraft's velocity and closure rate. A white arc indicates spacing in 30 seconds at the current closure rate, without indicating the impact of changing the speed commanded from the autopilot.

Display 3 changes the arc color to magenta. This arc, referred to as the "what if" arc, indicates predicted position changes in speed so that the pilot can see an immediate spatial presentation of the results of a possible adjustment in speed commanded from the autopilot.

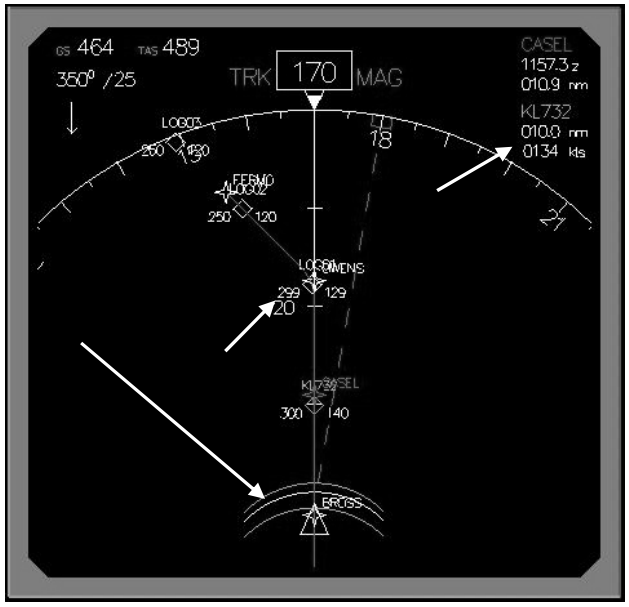

Figure 2: Display 2, Presenting Position, Velocity, Closure Rate, and Predicted Spacing of the Other Aircraft

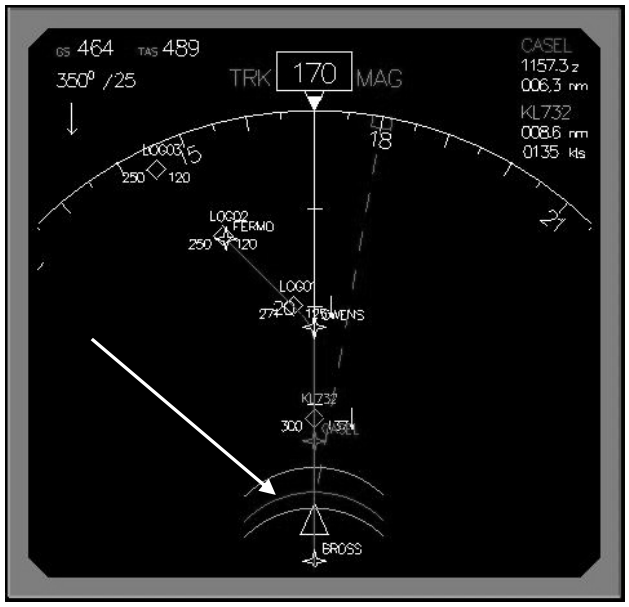

Figure 3: Display 3, Presenting Position, Velocity, Closure Rate, and "what if " Spacing of the Other Aircraft

RESULTS

Experimental data included both pilot performance at the spacing task (in terms of position error measured relative to the spacing commanded by the air traffic controller), and a modified NASA-TLX workload analysis that each pilot completed at the conclusion of each flight.

A statistically significant improvement in pilot performance was found in conditions with Display 2 or 3 in comparison to Display 1, with negligible differences between Displays 2 and 3. The improvement in pilot performance resulted in approximately 60% smaller aircraft positioning errors. A higher descent rate resulted in less velocity differential between aircraft for pilots using Displays 2 and 3. Likewise, Display 2 corresponded to the fewest number of pilot control inputs in performing this task, which is generally considered to correspond to better passenger comfort, a more stable flight path, and lower pilot workload.

Pilot responses on the TLX questionnaire confirm this improvement. While pilots felt that they performed better using the more-familiar Display 1, they also clearly indicated that they felt less frustration when using either Display 2 or 3 in comparison to Display 1. Additionally, pilots' perceived effort showed a significant decrease from Display 1 to Display 3.

CONCLUSIONS: APPLICATIONS TO DISPLAY DESIGN

The results demonstrate that pilots, given adequate traffic information, may be capable of taking over some additional control responsibility within controlled airspace. Pilot self-reported assessments of workload highlighted that their workload during this task, while impacted by the display, was manageable in all conditions. The display can therefore be examined principally in terms of its ability to foster better performance at the spacing task by presenting the information needed by the pilots in a format and with a presentation that corresponds the most directly to their use of the traffic display and autopilot systems.

In this study, performance benefited from the presentation of velocity and closure rate, given here through both a spatial presentation (spacing arcs) and textual presentation. However, the additional user-adaptable 'what-if' spacing arc provided no added value, at least with the presentation used in this study. This may indicate a limit on the amount of information that the pilot can feasibly consider during the high-tempo periods of this operation; it may also suggest instead that the short-look ahead time implicit in the prediction function used to place this arc, or the presentation of the arc, may have masked any benefit that could be achieved from presenting the pilot with this information.

ACKNOWLEDGMENTS

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