An Investigation of Flight Deck Data Link in the Terminal Area

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Time-based scheduling provides runway arrival schedule and time constraints for arriving aircraft.

En route speed & path assignments deliver aircraft so they are correctly spaced for descending on the profile.

Flight crews fly VNAV descents along RNAV RNP route – largely without controller intervention.

Aircraft are delivered to TRACON meter fixes according to a time-based schedule. Aircraft arrive with spacing errors that need to be reduced to maximize throughput and minimize spacing violations.

TRACON controllers correct residual spacing errors and cope with disturbances & off-nominal events using tools based on 4D trajectories.

All aircraft are have advanced flight deck automation and a significant number of the aircraft are assumed to be equipped with data link for trajectory clearance delivery.

Concept for Arrival Aircraft on RNAV- Required Navigation Precision (RNP) /Optimal Profile Descents (OPD)
Data Link and NextGen/SESAR

- NextGen and SESAR have operational procedures intended for terminal area implementation
- These procedures will continue to require the use of more data transfer for automation
- Data link has benefits and drawbacks for clearance delivery in the terminal area
- Few studies have focused on terminal area data link
Outline

- Background
- Objectives
- Methods
- Results
- Summary
- Next Steps
Data link is an enabling technology for NextGen/SESAR

- Allows for message permanence to handle long, complex messages for trajectory-based operations
- Enables broader use of automation
- Allow for direct entry of data into flight deck automation, which may reduce pilot errors (Logsdon, 1996)
Controller Pilot Data Link Communications (CPDLC) to address voice frequency constraints
- Maastricht Control Center
- Future Air Navigation System 1/A (FANS 1/A)

Data link is not expected to fully replace voice due to equipage and operational constraints
Background

- Data link research suggests that its use addresses existing voice communications problems, but creates new issues (Kerns, 1999; van Gent, 1995)
- Data link does not appear to reduce workload, but redistributes it (Kerns, 1991)
  - Current implementations of flight deck data link are textual/visual
  - Message permanence allows for interruption of communication tasks
- Data link has longer crew response times (Lozito et al., 2003) which may be particularly important for the terminal area
Objectives

- Examine the use of a current-day flight deck data link in the terminal area (San Francisco-SFO)

- There were three primary variables of interest
  - Message modality (voice and data link)
  - Message length (short and long)
  - Strategic v. tactical messages

- Impact of these variables upon communication efficiency was investigated
  - Response times
  - Communication clarifications and errors
Methods
Simulation Details

- Human-in-the-loop simulation
- Ten Boeing 747-400-qualified crews
- Boeing 747-400 Level D simulator
- Six scenarios per crew (35 mins each) in SFO terminal area
- All scenarios had a mix of data link and voice clearances
- Data link messages from RTCA Message Set
- Controller and pseudopilot as a confederate
- Some background traffic was provided
- Questionnaires and measures
  - ATWIT (Air Traffic Workload Input Technique)
  - Questionnaires post-run and post-simulation
Data Link Message Example

2046z ATC UPLINK 1/1
STATUS OPEN
AT CINNY CLEARED ROUTE CLEARANCE,
EXPECT ILS28R.MENLO,
MAINTAIN FL370.
<STANDBY LOAD>
<REJECT ACCEPT>
<PRINT LOG>

INIT REF RTE CLB CRZ DES
DIR INTC LEGS DEP ARR HOLD
ATC FIX PROG EXEC
PREV PAGE NEXT PAGE
Experimental Procedure

- Briefing and training on data link
- Crews used their company data link procedures
- Each crew flies 6 scenarios into SFO terminal area
  - 3 different routes
  - Each flown twice
Routes in the SFO terminal

- Oceanic
- Big Sur
- Modesto
Experimental Procedures (2)

- Total of ~16 messages per scenario
- 50% messages in each scenario voice, 50% data link
- 50% of the messages in each scenario were strategic: Conditional clearance messages with a temporal constraint
  
  e.g., “Cross BOLDR at and maintain 10,000 feet”

- Short messages (1 element) v. long messages (3 elements)
  
  “Cleared for the Modesto 3 arrival
  Cross CEDES at 11,000 feet and
  Cross OOMEN at or below 7000 feet”

  - Element refers to speed, route, or altitude component
  - About 5 of each per scenario

- Autoload messages v. manual load messages
  
  - About 4 autoloadable messages in one half of the scenarios
  - Compare to manual load messages with same message content
Results
Acknowledgment Times

- Acknowledgment time definitions
  - Voice: When controller begins speaking to end of pilot’s speech
  - Data link: From crew notification of message to when crew has “accepted” or “rejected” the message

- Data link acknowledgment times were significantly longer than voice acknowledgment times (p<.001)

- Data link messages that could be autoloaded had longer acknowledgment times v. those that required manual loading
Longer times for data link autoload was unexpected; possibly associated with pilots’ cross-checking of autoload entry into the Flight Management System (FMS)
Clarifications and Errors

- Clarification and errors seen as indication of crew confusion
- Clarification: A query related to the content of an ATC message between the pilots or between a pilot and controller (e.g., “what was our speed?)
  - Within crew clarification: between crew members
  - Air-ground clarification: between pilot and controller
- Error: An erroneous statement (not action) related to the content of a ATC message between the pilots or between a pilot and controller (e.g., “He gave us 250 on the speed” when actual clearance statement was 260)
  - Within crew error: between crew members
  - Air-ground error: between pilot and controller
Number of Clarifications and Communication Errors by Communication Mode

- No significant differences for clarifications
- Significant difference between data link and voice for communication errors ($p < .05$)
Means reveal more air-ground (pilot to controller) clarifications and errors in voice compared to data link.

Data link message has permanence, and reduces air-ground voice errors.
Number of Clarifications and Errors by Conditionality of Message, Mode, and Interaction type

- Significantly more clarifications and errors for conditional clearances (errors: $p<.001$; clarifications: $p<.001$)
- Confusion about clearance content and temporal constraints of clearance
Number of Clarifications and Errors by Length of Clearance, Mode, and Interaction Type

- Significantly more clarifications (p<.01) and errors (p<.001) for long messages
- More air-ground clarifications for long voice messages when compared to short voice messages and data link messages
- Voice messages encourage the use of voice frequency
Debrief Comments

- Pilots generally thought data link was acceptable in the terminal area.
- Some pilots stated the need for a better implementation of the flight deck data link.
- Pilots endorsed the autoload capability for reducing heads-down time and data entry steps.
Summary

- HITL investigating the use of a current-day flight deck data link for terminal-area NextGen/SESAR clearance
- Longer data link acknowledgment times
- General reduction in air-ground clarifications in long data link messages compared to long voice messages
- Strategic (conditional) clearances being considered for NextGen/SESAR may introduce an increase in crew confusion
Next Steps

- The use of other flight deck implementations of data link for NextGen/SESAR automation tools
- Simulation integrating flight deck and ground automation for data link messages
THANK YOU!

QUESTIONS?