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An analysis of air traffic controller-pilot miscommunication in the NextGen environment

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A B S T R A C T

This paper extends research on miscommunication between air traffic controllers and pilots by developing statistical models that predict the outcome of communications within the scope of controller-pilot data communications in the Next Generation Air Transportation environment. A database of controller-pilot voice messages from high and super-high altitude en-route sectors of US airspace is investigated. Emphasis is given to parameters that can be utilized in the voice-only communication, as well as in the mixed media, environment. This allows formulation of reasonable assumptions about the impact of data communications on controller and pilot behavior. The models indicate that the most important factors affecting communications are length and context of the message, entering of an aircraft into a sector, transfer of communication, and radio frequency congestion. The results also suggest that the transmission of non-time critical routine messages via data communications could reduce the number of communication errors and alleviate radio frequency congestion.

1. Introduction

The Next Generation Air Transportation System (NextGen), the latest generation of US aviation improvement plans, is intended to fundamentally change air traffic controller and pilot interactions. Current controller-pilot data communications (CPDLC) by radio comprise many types of information, including tactical commands to alter flight paths, strategic messages used to maximize longer-term flight and airspace efficiency, and routine information that is often repetitive or advisory but nonetheless required by current air traffic control rules. A key pre-requisite to enhancing the capacity and efficiency of the aviation system lies in providing tools to controllers and pilots that reduce the workload associated with such communications. Nearly all future automation and operational concepts that address these issues are dependent upon data communications (Data Comm) and will be implemented in NextGen.

According to the Federal Aviation Administration's (FAA) (2011) data communication roadmap, CPDLC will be implemented in the National Airspace System (NAS) in two segments. Segment 1 will be introduced in 2015 for airport tower service, and in 2018 for en route service. In general, it will include Data Comm initiation capability, four-dimensional trajectory management, communications management, stuck microphone checks, en route clearances, ground-issued clearances and taxi instructions. Segment 2 will be introduced in 2025 by adding further four-dimensional trajectory agreements and trajectory clearances, and information on status, delay, and constraints within the NAS. Segment 2 will be concerned with expanding the use of Segment 1's services to include terminal control areas.

Although the mixed use of voice and data messages is expected to alleviate radio-frequency congestion (Federal Aviation Administration Technical Center, 1990), it is not clear if controller workload will be reduced. Analysis by Rakas and Yang (2007) addresses the problem of multiple open transactions and the occurrence of delayed responses in the mixed environment, and suggests that an increase in open transactions affects controller mental workload and thus increases the likelihood of miscommunication occurrences. Waller and Lohr (1989) and Cardosi and Boole (1991) also show that the transfer time of Data Comm messages is significantly longer compared to voice messages; a lag caused mostly by reduced pilot alertness to data messages that results in delayed responses. Further, the time required for message composition in lengthier data communications can be important.

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2. Data

The database consists of 7965 transcribed controller-pilot messages from 42 thirty-minute voice communication recordings, and accounts for about 8% of the en route messages exchanged during a typical hour in US airspace.[1] The samples are provided by MITRE and the FAA Technical Center, and were derived from 33 sectors in five air route traffic control centers (ARTCCs) of US airspace: Indianapolis (ZID), Memphis (ZME), Denver (ZDV), Dallas-Ft. Worth (ZFW) and Atlanta (ZTL). The selected sectors are representative of the NAS in terms of complexity, size, and traffic volume. The analysis focuses on sectors of high (H) and super-high (SH) altitude, only.

Data were derived from the transcribed messages, but only 13 fields (Table 1) were required for formulating the model variables. Miscommunication messages were defined as those that resulted in errors based on their sequence, text and type. For example, if a clearance was acknowledged by an incorrect read-back, only the clearance and not the read-back were considered as a miscommunication. Particular attention was given to all call-back and read-back messages, while backtracking of all related messages was done to determine the origin of each call-back and read-back.

3. Methodology and results

Classifying the 382 miscommunication messages by causes we find that 74% are due to; pilot mishearing (28%), pilot not responding (20%), controller mishearing (15%), and controller not responding (11%). The majority of the remaining miscommunications were messages sent by controllers to aircraft that either had not yet checked-in with the sector or had already handed off from it. Here all messages are divided according to their recipient; pilot or controller. For each group, a pair of similarly structured models is developed by examining whether a message resulted in a miscommunication or not; recipients of messages are controllers in Model 1 and pilots in 2. The type of miscommunications – mishearing and not responding – are further analyzed in Models 3 and 4. The four models are shown in Fig. 1.

Based on the data fields, the following independent variables are used:

1. *Open transactions = number of simultaneously open transactions*
2. *Interval = message duration (in seconds)*
3. *Arrival = one if an aircraft arrives into a sector; zero for all others*
4. *Communication transfer = one if a message refers to hand-off; zero for all others*
5. *Cumulative arrivals*
6. *Cumulative departures*
7. *Number of aircraft*
8. *Number of contacts*
9. *Monitor alert parameter (MAP)*
10. *Volume/capacity*
11. *Sector frequency occupancy*
12. *Dynamic frequency occupancy*

A basic property of the variables, except "interval", is that they can be utilized in the voice-only communication environment as well as in the mixed media (voice and Data Comm) environment.

Table 1
Description of the data fields.

Field name	Description
Sector	Sector name
Sender	Pilot (p) or controller (c) speaking
Code	Aircraft code
Text	Message text
Message type	Message type
Miscommunication	One if a message results to miscommunication, zero for all other
Open transactions	Multiple open transactions
Reasons	Reasons in case of a miscommunication
Tsec	Time each message (transaction) starts (in seconds)
Arrival	One if an aircraft arrives into a sector, zero for all other
Departure	One if an aircraft departs from a sector, zero for all other
Aircraft	Estimated aircraft in sector
MAP	Monitor alert parameter

Although interval is a metric for voice messages only, it provides a rough indication of the message's complexity, and the results obtained from its analysis can be expanded for the Data Comm system.

The open transactions parameter is a metric introduced by Bolic et al. (2005) and captures the increase in controller mental workload due to simultaneous awareness of more than one open transaction. A transaction includes all messages exchanged between a pilot and a controller until the communication's purpose is achieved, and is considered open during the time that it is unresolved. While a transaction remains open, controllers may initiate additional transactions with other aircraft. The existence of multiple open message transactions affects controller cognitive utilization and the occurrence of miscommunications, particularly in terms of delayed responses.

The number of aircraft is defined as those inside the sector when the message transaction starts. The aircraft that were present at the beginning of the recording were estimated by counting those for which no initial call had been recorded. Then adding and subtracting cumulative arrivals and departures finds the aircraft present at each time. The number of contacts is the sum of initial contacts and communication transfers from the beginning of the recording until the examined message was sent (cumulative arrivals plus cumulative departures). Since these message types are

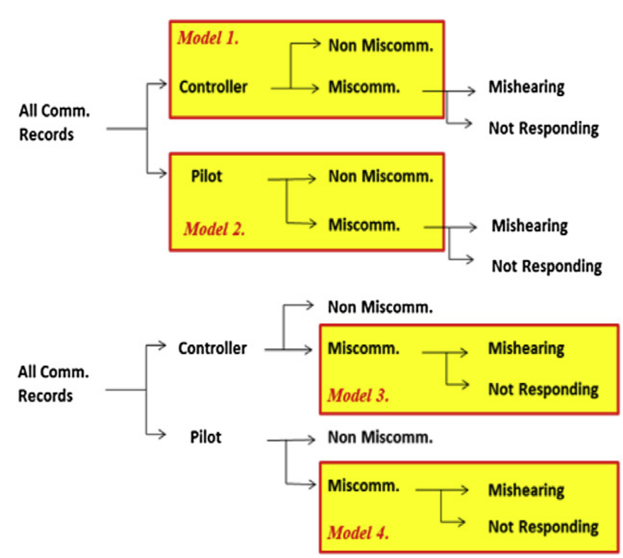

Fig. 1. Representation of Models 1, 2, 3 and 4.

[1] The voice samples used are derived from sectors with different sizes and traffic characteristics, making it reasonable to assume that the data set is representative of the US airspace. A 1-h recording in each of the 260 high/super-high altitude sectors in US airspace would result in 260 h of voice communication. Our sample consists of 21 h of voice recordings.