Analysis of Reportable Events in Kansas City Air Route Traffic Control Center

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The implementation of Controller-Pilot Datalink Communications (CPDLC) in domestic en route airspace will change the controllers' and pilots' tasks, which will, in turn change the types of observed errors. This study characterizes the current (pre-implementation) pilot and controller errors at the expected initial implementation site for CPDLC. The analysis included 1,761 mandatory occurrence reports (MOR); 670 reports related to pilot/controller error—nearly 70% of these related to loss of communication. The majority (20%) of reports that included information on how the event was discovered involved an aircraft that was transferred into a sector without radio communications. Loss of communication events tended to be more frequent for General Aviation than for Commercial aircraft. Of the reports that cited a potential cause for the loss of communication, the most common cause was mechanical issues, followed by the failure of the controller to issue the frequency change or the issuing of the wrong frequency. Forty-three Pilot Deviation occurrences were examined—the majority of these included a loss of communication event. Many of the identified factors could be mitigated by CPDLC. These results contribute to a baseline of communication performance, prior to the implementation of CPDLC, and can be compared to a future analysis of post-implementation performance.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in²	square inches	645.2	square millimeters	mm²
ft²	square feet	0.093	square meters	m²
yd²	square yard	0.836	square meters	m²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km²
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
		NOTE: volumes greater than 1000 L shall be shown in m³		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
oz	ounces	28.35	grams	g
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m²	cd/m²
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm²	square millimeters	0.0016	square inches	in²
m²	square meters	10.764	square feet	ft²
m²	square meters	1.195	square yards	yd²
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi²
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.314	cubic feet	ft³
m³	cubic meters	1.307	cubic yards	yd³
mL	milliliters	0.034	fluid ounces	fl oz
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
g	grams	0.035	ounces	oz
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m²	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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Acronyms and Abbreviations

ASAP	Aviation Safety Assurance Program
ATC	Air Traffic Control
ATQA	Air Traffic Quality Assurance
CEDAR	Comprehensive Electronic Data Analysis and Reporting
CPDLC	Controller-Pilot Datalink Communications
EOR	Electronic Occurrence Reports
FAA	Federal Aviation Administration
FMC	Flight Management Computer
GA	General Aviation
MOR	Mandatory Occurrence Reports
NextGen	Next Generation Air Transportation System
NORDO	No Radio
ZKC	Kansas City Air Route Traffic Control Center
PD	Pilot Deviation
SD	Standard Deviation
TCAS	Traffic Alert and Collision Avoidance System
VHF	Very High Frequency

Preface

This report was prepared by the Aviation Human Factors Division of the Safety Management and Human Factors Technical Center at the John A. Volpe National Transportation Systems Center. It was completed with funding from the Federal Aviation Administration (FAA) Human Factors Division (ANG-C1) in support of the FAA Office of Flight Standards (AFS-470). We are thankful for our support from ANG-C1, including Regina Bolinger, Dr. Sheryl Chappell, Joey Jaworski, and Nick Lento. We would like to thank our technical sponsors, Mark Patterson (AFS-470), Tom Kraft (AIR-100) and Dr. Kathy Abbott (AIR-100) for their support. We thank Jeffrey Loague (ATO) for sharing his expertise and providing the Mandatory Occurrence Reports.

For questions or comments, please e-mail Kim Cardosi (kim.cardosi@dot.gov).

Executive Summary

The implementation of Controller-Pilot Datalink Communications (CPDLC) in domestic en route airspace is a key enabling technology for many Next Generation capacity and safety enhancements. This implementation will change both the controllers' and pilots' tasks, which will in turn, change the types of observed errors. The present study characterizes the current (pre-implementation) pilot and controller errors at the expected initial implementation site, Kansas City Air Route Traffic Control Center (ZKC). Two years of reportable events, from Mandatory Occurrence Reports (MORs), Electronic Occurrence Reports (EORs), and Pilot Deviations (PDs), were examined.

The analysis included 1,761 MOR reports; of these 670 reports related to pilot/controller error—nearly 70% of these events were related to loss of communication. The majority (20%) of reports that included information on how the event was discovered involved an aircraft that was transferred from one sector to the next as NORDO (No Radio) Loss of communication events, which tended to be more frequent for General Aviation (GA) than for Commercial aircraft. When the duration of the event was reported, the mean duration for GA aircraft was 28 minutes (median = 21 minutes, range between 2-100 minutes); the mean duration for commercial aircraft was 20 minutes (median = 10 minutes, range between 3-94 minutes). As expected, losses of communication were longer for GA compared to commercial aircraft. Of the reports that cited a potential cause for the loss of communication, the most common cause was mechanical issues (24%), followed by the failure of the controller to issue the frequency change (22%) or issuing the wrong frequency (14%). Thirteen percent of the events were attributed to pilot error (e.g., dialing the wrong frequency, misunderstanding the frequency, or forgetting to change frequency). While it is not possible to determine whether these identified causal factors are representative of all lost communication MORs, it is clear that many of the identified factors could be mitigated by CPDLC. Analysis of MORs with Airspace/Altitude/Route/Speed and Airborne Separation errors further determined that 22% of these could have been mitigated with CPDLC.

Forty-three PDs occurring in ZKC were examined—the majority of these reports (49%) included a loss of communication event; 40% involved an altitude deviation. Similar to the MOR data, most of these events concerned GA aircraft. For 84% of all PDs, CPDLC was identified as a potential mitigation.

These results contribute to a baseline of ZKC communication performance, prior to the implementation of CPDLC, and can be compared to a future analysis of post-implementation performance. Examining the frequency and nature of errors before and after the implementation of en route CPDLC helps ensure that projected benefits have been realized and no unintended sources of error have been introduced.

1. Introduction

The implementation of Controller-Pilot Datalink Communications (CPDLC) in domestic en route airspace is a key enabling technology for many capacity and safety enhancements identified in the Next Generation (NextGen) Air Transportation System (NextGen Implementation Plan, 2015). This implementation will change both the controllers' and pilots' tasks.

In particular, the introduction of CPDLC to the en-route environment is expected to change the types of observed errors. Readback/hearback errors and pilots accepting a clearance intended for another aircraft would be expected to decrease. One of the benefits of CPDLC is that it can allow complex route information to be loaded into the Flight Management Computer (FMC) with minimal data entry; this alleviates the need for flightcrews to rely on memory for information received from Air Traffic Control (ATC) in addition to reducing the frequency of speech-related communication errors.

Some of the projected benefits associated with the use of CPDLC in the en-route environment—reduced workload (for both controllers and pilots), and reduced voice channel occupancy time (and hence, reduced frequency congestion)—are based on the transfer of communication using an instruction to the pilot to monitor the next assigned frequency, as opposed to contacting the controller on that frequency. One concern with this projected shift from "contact" to "monitor" is that it might affect the ability of a controller to contact an aircraft on frequency. That is, there is a perception that the requirement for a voice check-in increases the chances of the controller being able to contact the aircraft when needed, over a "silent check-in" associated with a MONITOR instruction. The controller's ability to quickly contact the aircraft via voice—to issue tactical clearances to assure separation—will continue to be safety critical in the CPDLC environment. However, the ability of the controller to use CPDLC to send an instruction to the pilot to contact the desired frequency should help to decrease the number and duration of loss of communication (lost comm) incidents for equipped aircraft.

The purpose of this study was to examine at least one year's worth of Federal Aviation Administration (FAA) safety data to characterize the pilot and controller errors that contributed to reportable events. Reports were examined from Kansas City Air Route Traffic Control Center (ZKC ARTCC), since this is the area of initial en route implementation of CPDLC. The results will contribute to a pre-implementation baseline to compare to post-implementation measures. Examining the number and nature of errors before and after the implementation of en route CPDLC can help to ensure that projected benefits have been realized and no unintended sources of error have been introduced.

2. FAA Safety Data

FAA Order JO 7210.632, Air Traffic Organization Occurrence Reporting, defines reportable occurrences for the collection of safety data, including both Mandatory Occurrence Reports (MORs) and Electronic Occurrence Reports (EORs). The intent of MORs is to capture information on all suspected unsafe air traffic occurrences, such as suspected losses of separation, airspace violations, and deviations involving altitudes, routes, or speeds that do not involve a loss of separation. MORs can be attributed to pilot error (Pilot Deviation) or to controller error. MORs are put into the Comprehensive Electronic Data Analysis and Reporting (CEDAR) database. To complement the information contained in MORs, EORs are electronically generated by automation (Operational Error Detection Program) when a possible violation has occurred. The intent is to capture information on losses of separation that may be missed in MOR reports submitted by controllers. A subset of the MOR and EOR data that is routinely analyzed by FAA is referred to as a Validated Loss of Standard Separation.

To quantify and characterize relevant errors in ZKC airspace, MORs, EORs, and Pilot Deviations (PDs) occurring in ZKC airspace were examined.

2.1 Mandatory Occurrence Reports (MORs)

There were 1,761 MORs submitted between March 1, 2013 and April 30, 2015. As shown in Figure 1, MORs are categorized by:

- losses of airborne separation,
- airspace/altimeter/speed or heading errors,
- loss of communications,
- emergencies,
- service integrity issues,
- responses to public inquiries, and
- airport environment.

The majority of the reports examined described events that were unrelated to human error and unlikely to be affected by the implementation of CPDLC. These included 564 reports of emergencies (mechanical, fuel, medical, etc.), 518 reports on service integrity (ATC equipment issues), 5 reports in response to public inquiries, and 4 reports concerning the airport environment (e.g., a closed runway). The remaining 670 reports were analyzed in detail, since they identified pilot and controller errors that resulted in, or could have resulted in, a loss of standard separation. Of these 670 reports of interest, the vast majority of events (471 reports or 70%) involved communication.

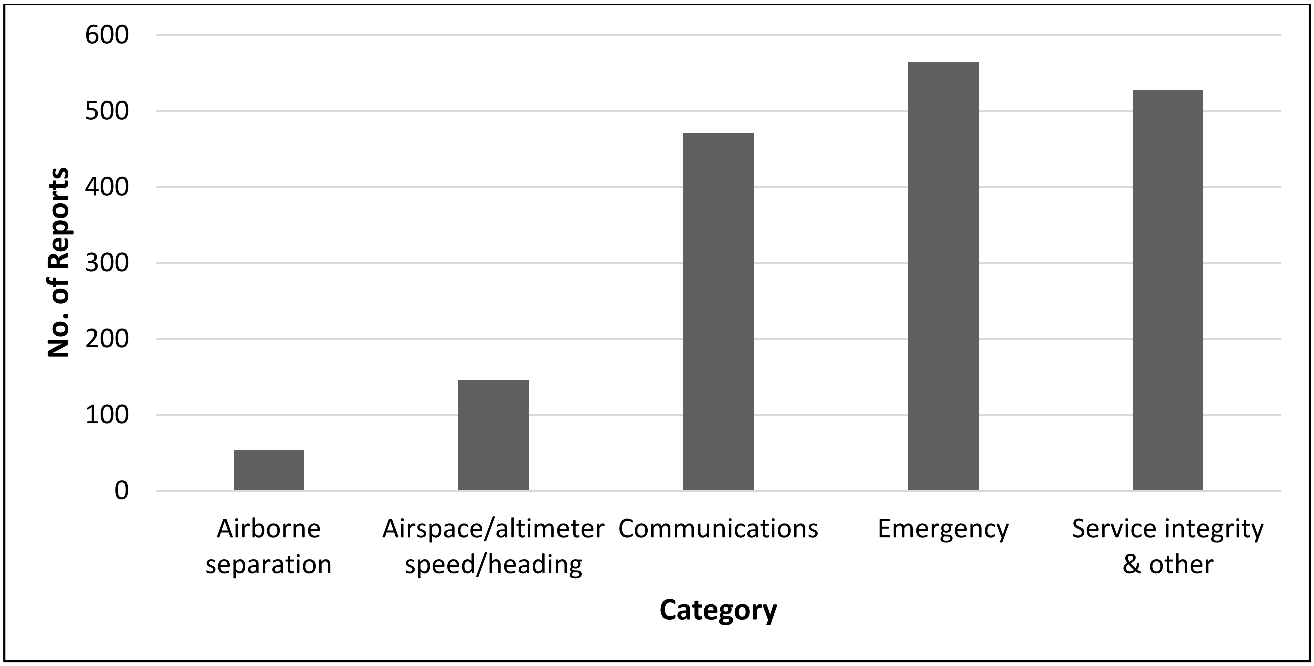

Figure 1. Number of Reports by MOR Categories.

2.1.1 Loss of Communication

According to FAA Order JO 7210.632, controllers should report: "Any instance in which communication with an aircraft was not established or not maintained as expected/intended, and results in alternative control actions or additional notifications by ATC, or a flightcrew, or in a landing without a clearance" (p.11). For these 471 communication events, the reports were analyzed to characterize: 1) how a loss of communication was discovered, 2) the type of operation, 3) the duration of the lost communication event, and 4) the cause of the loss of communication. Where appropriate, we also compared the report to those of a previous, more extensive analysis of 1,315 loss of communication MORs occurring across all domestic airspace at Air Route Traffic Control Centers (ARTCCs) between March 1, 2014 and October 1, 2014 (Cardosi, 2015).

How the Loss of Communication was Discovered

Of the 471 reports, the vast majority (464, or 98.5%) were loss of communication events. The remainder involved anomalous events, such as communications with flight services, not pertinent to this analysis.

Of the 464 reported loss of communication events, 22% involved aircraft that was NORDO (No Radio) when it was transferred into the sector/center, another 26% contained no information as to how it was discovered that the aircraft was not on the correct frequency, and the remaining reports specified that the discovery was made by the ZKC controller. This was similar to the previous study in which 20% of the lost communication MORs identified the aircraft being transferred into the sector as NORDO (Cardosi & Lennertz, 2017).

Duration

Figure 2 shows the number and duration of the loss of communication events by type of operation. Since aircraft are not identified in the MOR as operating under FAA Part 121, Part, 135, Part 91, etc., the events were classified using the aircraft call signs. The 297 reports involving call signs using the registration number of the aircraft (N… for US registration, XA… or XB…. for Mexican, or CF… or CG… for Canadian) were classified as General Aviation (GA); the 157 call signs that included a company designator were classified as "Commercial". There were 10 reports in the third category of military aircraft identified by a tactical call sign and military aircraft type.

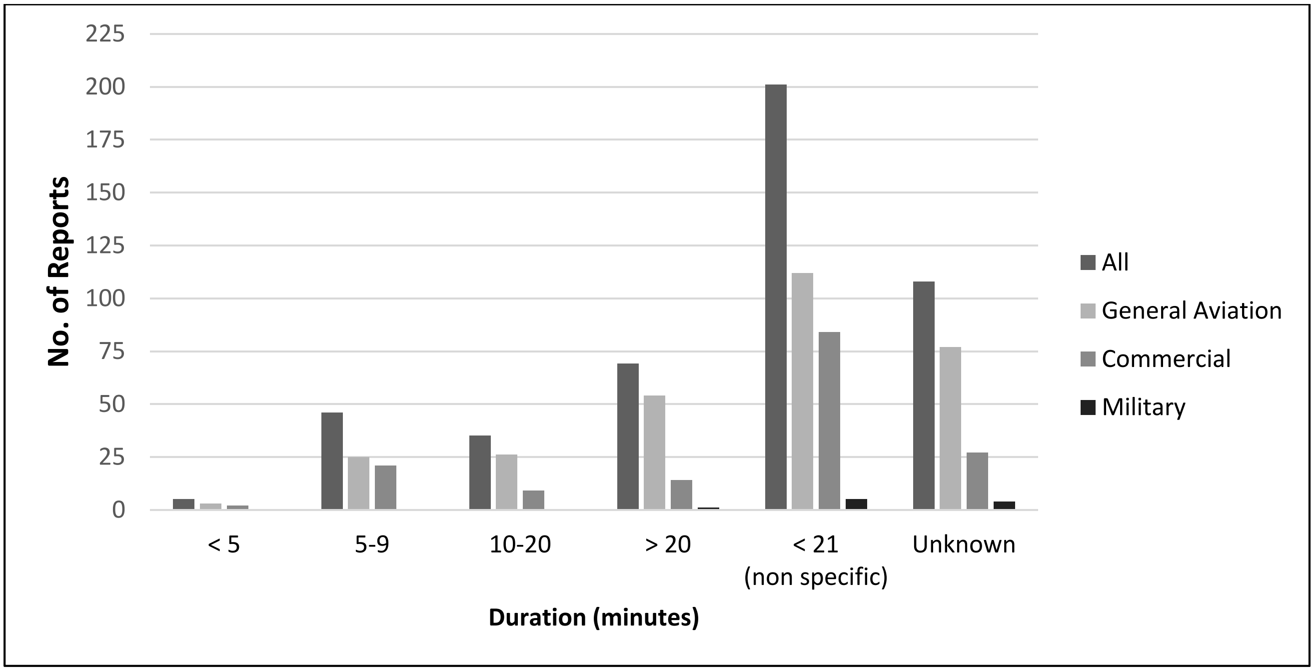

Figure 2. Number and Duration of NORDO Event by Type of Operation.

Twenty-six percent of the loss of communication reports contained no information on the duration of the NORDO event. When times were identified in the report, they most commonly referred to the time that *the controller in that sector* was unable to communicate with the aircraft and *not* the total time that the aircraft was not communicating with ATC.

Table 1 provides metrics on the duration of lost communication for the 155 events in which a precise time was noted.

Table 1. Duration measures (in minutes) for MOR Loss of Communication Events.

Operation Type	Mean	Median	Minimum	Maximum	Standard Deviation
Commercial (46 reports)	20	10	3	94	20
General Aviation (108 reports)	28	21	2	100	21
All (155 reports)	26	17	2	100	21

In the Cardosi and Lennertz (2017) study, the times reported for the loss of communication ranged from

1 to 235 minutes. Across all operations, the average reported loss of communication was 21 minutes (Standard Deviation [SD]= 19; median = 15). For GA aircraft, the mean duration for loss of communication events was 25 minutes (SD=22; median = 25). For commercial aircraft, the mean duration for loss of communication events was 16 minutes (SD= 15; median = 11).

Results from the current study and Cardosi and Lennertz (2017) indicate that the duration of loss of communication is longer for GA compared to commercial aircraft. This is not surprising for several reasons. Events involving a loss of communication between aircraft and ATC would be expected to be more common and of longer duration with GA aircraft than with commercial, air carrier flights. While some GA aircraft are quite sophisticated and operate with a crew of two – in general, commercial flights would be expected to miss fewer ATC calls than GA flights due to their (usually) better equipment and more frequent maintenance, and two-person crew (compared to typical GA single-pilot operations). Another critical difference is that when contact is lost, controllers are able to contact the company and have dispatch contact the aircraft, often via CPDLC.

Causal Factors

Only 55 (12%) of the reports identified reasons for the loss of communication. Figure 3 shows the multitude and frequency of identified causal factors. Of the 55 reports, 24% cited mechanical reasons for the loss of communication. Twenty-two percent stated that the controller failed to issue the frequency change and another 14% stated that the controller issued the wrong frequency. Thirteen percent were attributed to the controller's failure to catch a pilot's error in the readback of the frequency. Another 13% of the reports identified pilot error as a cause (dialing the wrong frequency, misunderstanding the frequency, or forgetting to change frequency); this included one pilot taking a frequency change intended for another aircraft.

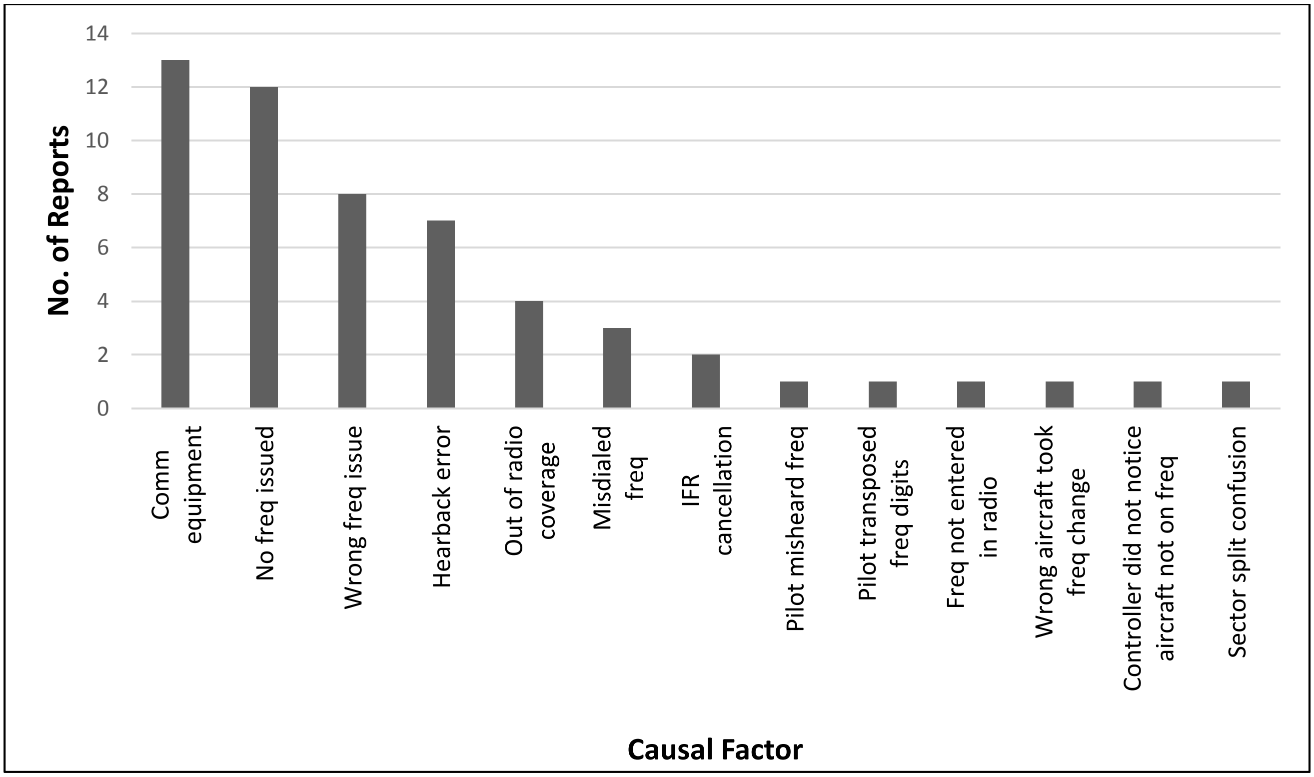

Figure 3. Number of Reports by Identified Causes of NORDO Events.

In contrast, in the larger study of loss communication events, Cardosi & Lennertz (2017) observed that almost 20% of the reports contained information as to the cause. Where a cause was identified, the most frequently cited causes were controllers issuing the wrong frequency or never issuing a frequency change (identified in 38% of the reports providing a cause, i.e., 7% of the total reports). Pilot error was identified in 4% of all of the reports.

While it is not possible to determine whether these identified causal factors are representative of all lost communication MORs, it is clear that many of the identified factors could be mitigated by CPDLC. Problems such as readback errors, taking another aircraft's frequency change, flying out of Very High Frequency (VHF) radio coverage, pilot misunderstanding the frequency, would certainly be positively affected by regular consistent use of CPDLC. However, NORDOs that result from controllers giving the wrong frequency, using the wrong call sign, not issuing a frequency change, and pilots misdialing a frequency would still be possible with CPDLC and greatly dependent on its implementation and required procedures for its use. For example, if a controller had the ability to automatically send a communication change with a CPDLC message on handoff acceptance, then 'forgetting' to issue a frequency would be mitigated. (The chances of sending the wrong frequency, however, would depend on the design of the controller interface, e.g., how many frequencies were available to select). On the flight deck, if the frequency in the CPDLC message was uploaded into the aircraft radios, the pilots would not misunderstand or make the mistake of misdialing the frequency into the radio.

2.1.2 Airspace/Altitude/Route/Speed (Deviation) and Airborne Separation

For the purposes of this analysis, the MOR categories of Airspace/Altitude/Route/Speed and Airborne Separation were combined, since the types of pilot and controller errors (described below) that contribute to each type of event are the same. Out of the 670 MORs of interest, 198 were in these categories. These events were examined for causal pilot and controller errors and the potential to be mitigated by CPDLC. An event was judged to be less likely to have occurred if the clearance had been transmitted via CPDLC and if it involved any of the following: readback error or hearback error of information that is expected to be able to be sent via CPDLC (e.g., altitude), pilot accepting a clearance intended for another aircraft, climbing/descending through an assigned altitude or climbing/descending without a clearance, and errors in which the controller issued one altitude but entered a different one in the data block. Forty-three (22%) of the 198 reports included these type of errors, which could have been mitigated by CPDLC. Of these 43 events, 34 (79%) were concerned with the aircraft's altitude. Nine of the 43 events involved a miscommunication or misunderstanding of the routing; this type of error could be mitigated with CPDLC especially with loadable clearances. Speed, heading and airspace issues did not occur with the exception of one particular event where a pilot mistook a heading for an altitude (this event was coded in this analysis as an altitude event):

> Aircraft 1 was at 170 and Aircraft 2 was opposite direction level at 160, requesting FL400. Controller instructed Aircraft 2 to Fly Heading 2-8-0. Aircraft 2 readback, 2-8-0, began a climb and separation was lost. Controller instructed Aircraft 2 to maintain 160. Controller asked Aircraft 2 what was the last assigned altitude and Aircraft 2 indicated he was cleared to 2-8-0.

Controller Coordination Errors

Lack of or untimely controller coordination, such as a delayed or non-existent handoff or point-out, is a common cause of controller error. Since the effects of CPDLC on controller coordination remain to be seen, the number of coordination errors will be important to track post-implementation. Twenty-six controller coordination errors were identified in the MOR data set and are included here as a component of baseline performance. Figure 4 shows the distribution of controller coordination errors.

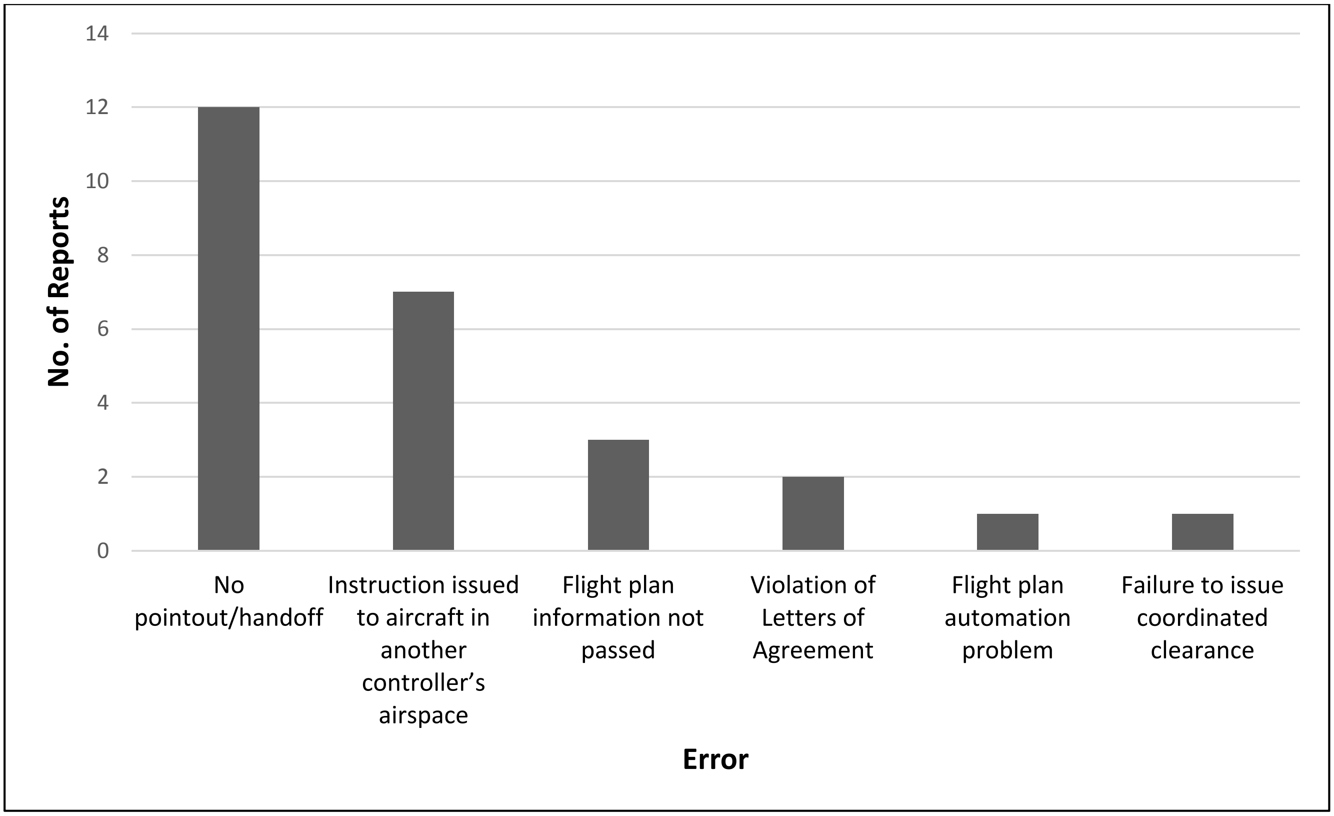

Figure 4. Frequency of Controller Coordination Errors.

The remainder of the Airspace/Altitude/Route/Speed and Airborne Separation MORs were primarily aircraft responding to Traffic Alert and Collision Avoidance System (TCAS) resolution advisories, airspace incursions, and incorrect equipment suffixes that resulted in a misapplication of Reduced Vertical Separation Minimum.

2.1.3 Emergency Events

None of the 564 MORs in the Emergency category described events related to controller or pilot error. These events described fuel emergencies, mechanical failures, or passenger emergencies. Only nine of the reports described radio failures or electrical problems affecting the radio. It was not possible to determine whether the problems encountered would have also affected the efficacy of CPDLC, since it is possible for electrical failures to adversely affect CPDLC. If the mechanical issues were limited to the radio, CPDLC could help to resolve the problems.

2.1.4 Validated Losses of Separation

A subset of the MOR/EOR data is the Validated Losses of Standard Separation. This data set contained 64 events between April 1, 2014 and March 21, 2016. Two of these events had no narratives or information associated with them; the remaining 62 events were analyzed. Of these events, 3 were MORs and 61 were EORs. As shown in Figure 5, 15 (23%) events were attributed to controllers' misapplication of visual separation procedures. Figure 6 shows pilot errors cited in validated losses of separation, the majority of which were related to missing an assigned altitude. The remainder of events were similar to the altitude events documented in the MORs with one exception: an anomalous event occurred because ATC had not issued the required altimeter setting to the pilot. While losses of separation resulting from improperly set altimeters are likely quite rare, these events are a prime candidate for mitigation via implementation of CPDLC.

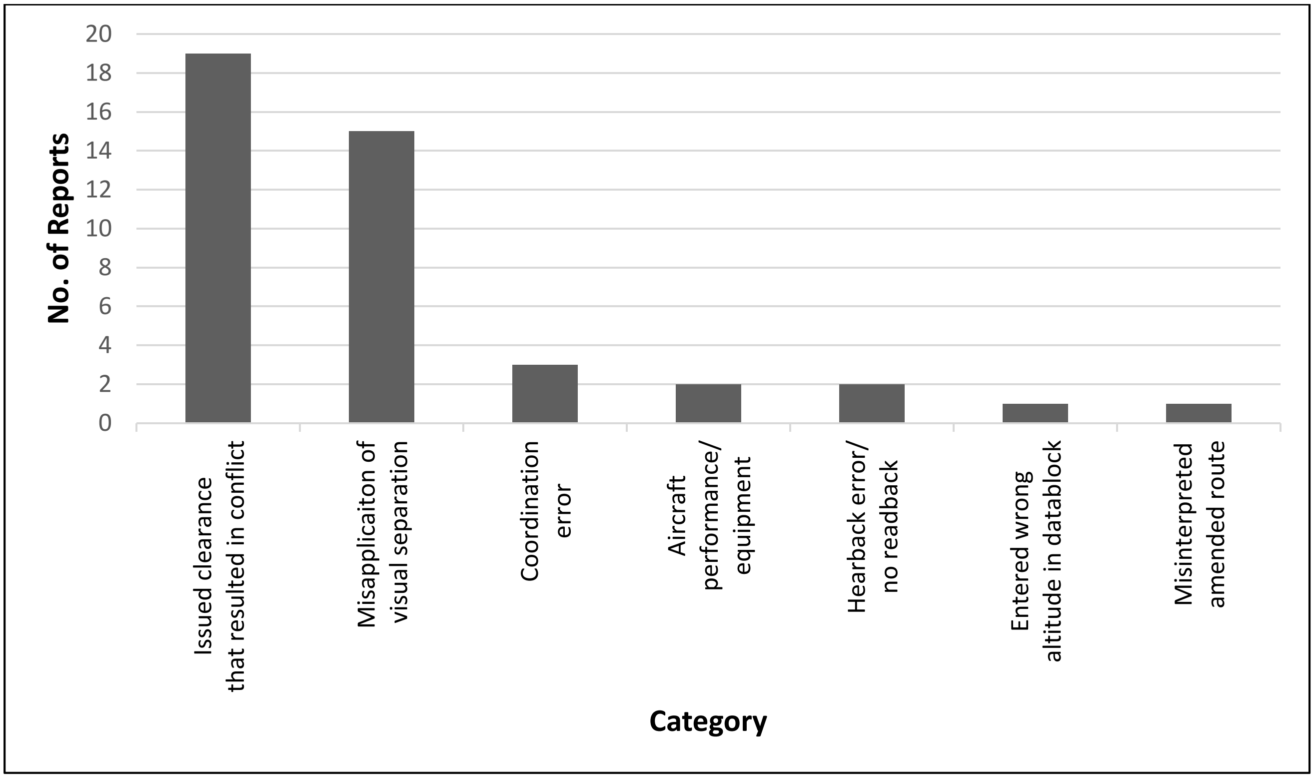

Figure 5. Frequency of Controller Errors Cited in Validated Losses of Separation.

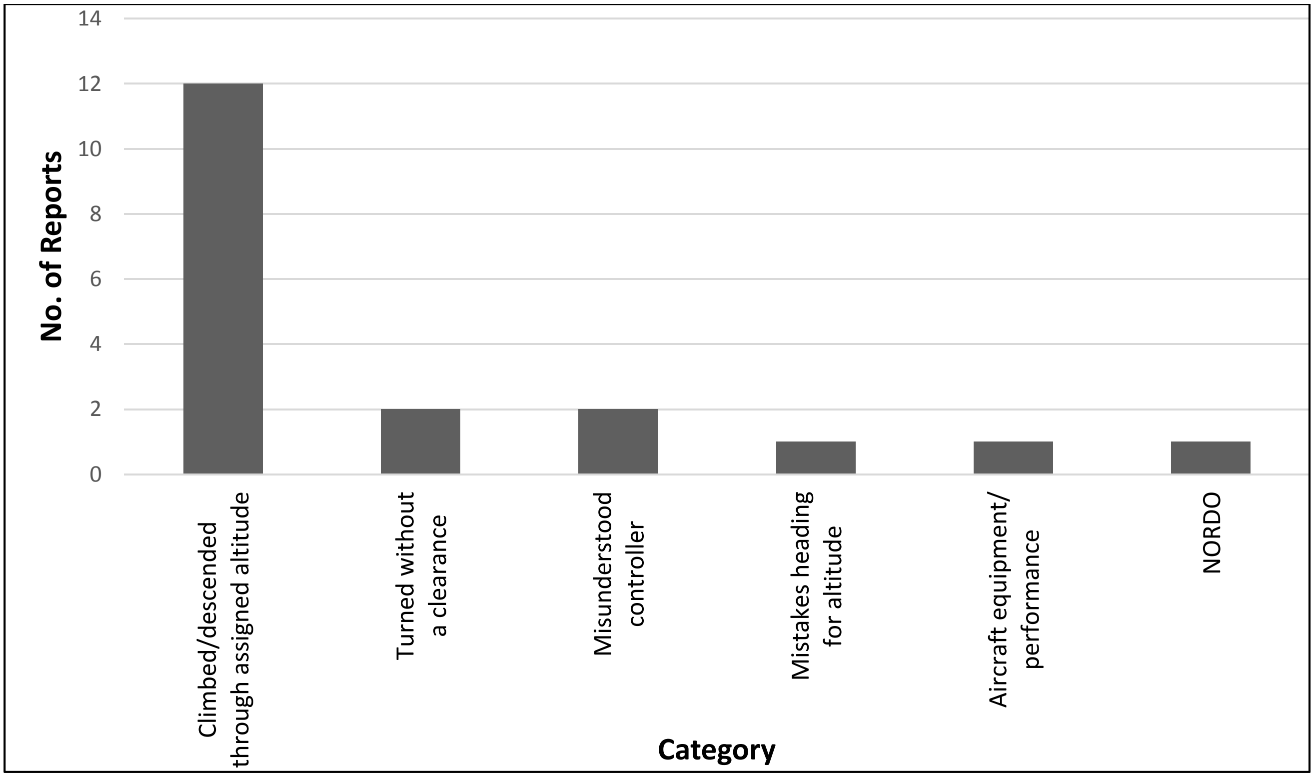

Figure 6. Frequency of Pilot Errors Cited in Validated Losses of Separation.

2.1.5 Electronic Occurrence Reports (EORs)

EORs are electronically generated by an automated system when a possible violation has occurred. EORs generally contain no narrative data, only succinct findings recorded by Quality Assurance specialists. Almost 10,000 EORs were recorded between March 1, 2013 and April 30, 2015. Only 8 of these 9,619 EORs included information on pilot or controller error that resulted in a possible loss of separation that was not included in the "Validated Loss of Separation" data set of the MORs. All but one of these events (in which no altimeter setting was issued) were similar to the altitude MOR events and were due to errors expected to be mitigated by CPDLC. Three events were due to the pilot climbing or descending through their assigned altitude, two were due to the controller missing an incorrect readback, one to the pilot changing altitude without a clearance and one to the pilot misinterpreting a clearance.

2.2 Pilot Deviation (PD) data

The FAA's Air Traffic Quality Assurance (ATQA) database was queried for PDs that occurred in the Central Region, ZKC facility, between January 1, 2014 and December 31, 2015. This yielded 43 unique final reports. While PDs are included in the MOR data set as events, the description of events in the PD data set is much richer than those in the MOR reports and contain more insights into causal factors.

As shown in Figure 7, 58% involved aircraft operating under Part 91 (General Aviation) and 23% involved aircraft operating under Part 121 (U.S. Air Carriers).

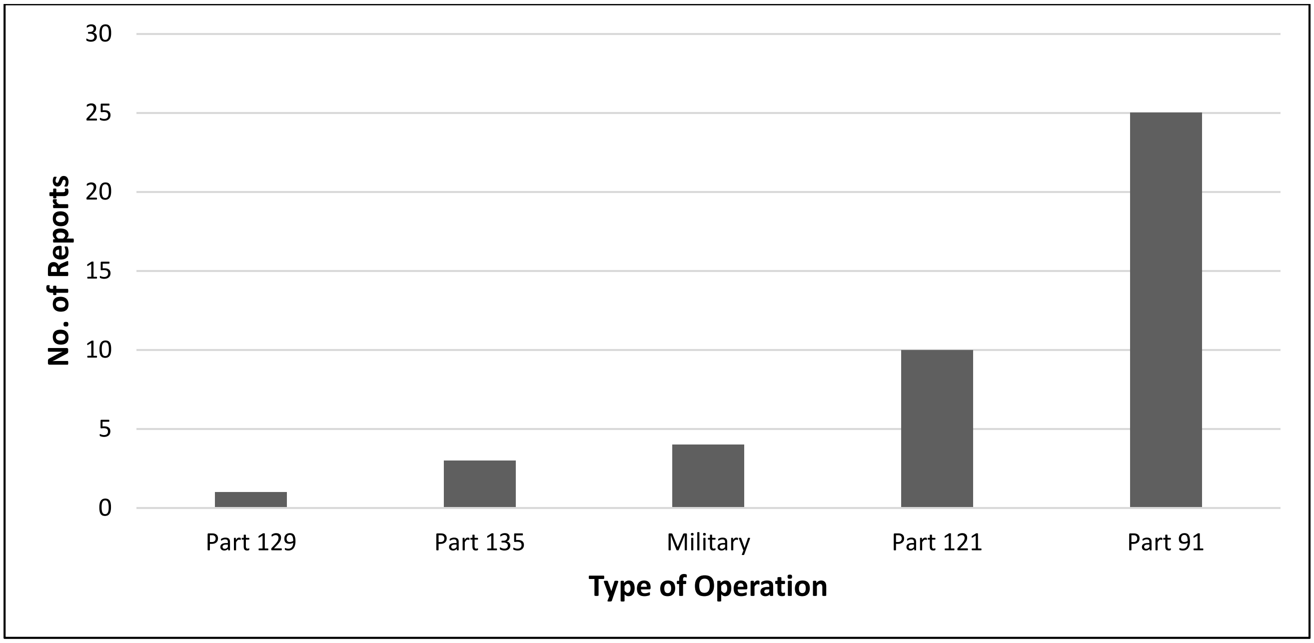

Figure 7. Number of PDs by Type of Operation

One of the 43 reports referenced an ASAP (Aviation Safety Action Program) report number and contained no information on the error. Each of the 42 remaining reports was categorized for its primary causal factor (e.g., loss of communication, altitude deviation, etc.). Unlike MOR data, the PDs can provide insights into the cause of the loss of communication since pilot interviews are typically included in the investigation of the incident.

2.2.1 Results

Figure 8 shows the distribution of errors in the PD reports. Two reports describe pilots (operating under Part 91) descending below their cleared altitude and then losing voice contact with ATC. The most commonly identified PD, cited in 49% of the PD reports, was a loss of communication with ATC.

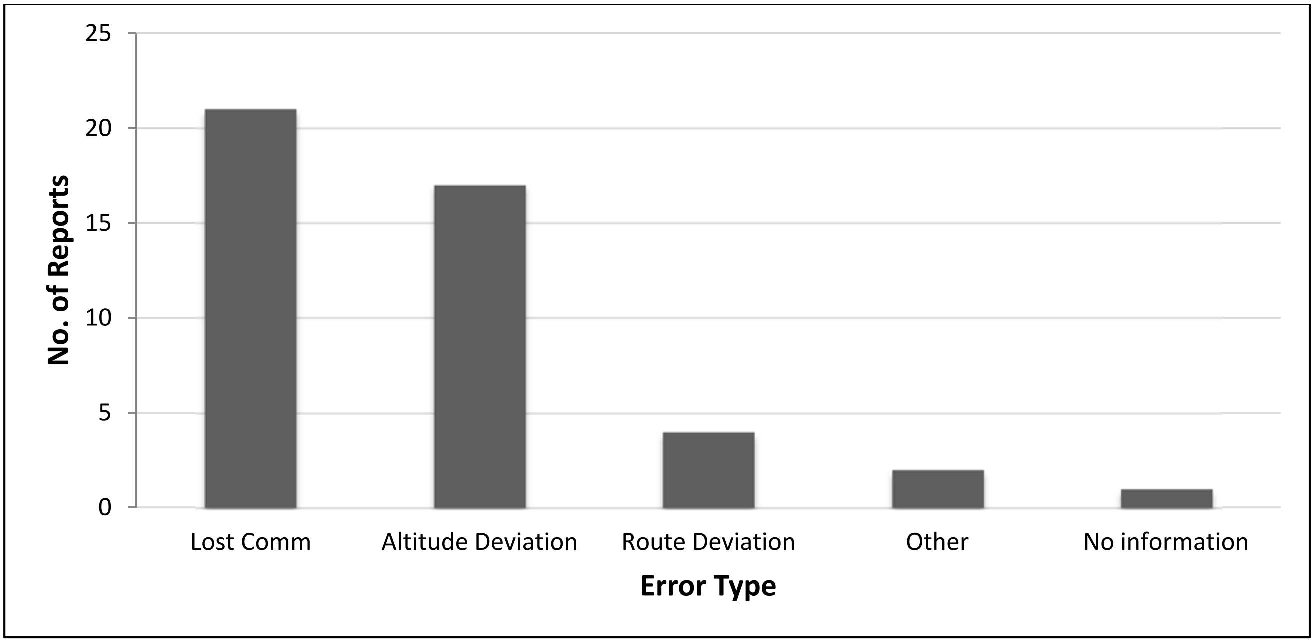

Figure 8. Number of PDs by Error Type.

Loss of Communications

All but one of the 21 loss of communication reports had some descriptive information on the error. As shown in Figure 9, two of these reports involved pilots flying under Part 121 operations, two involved Part 135 operations, one was military operations and the rest involved Part 91 operations. Of the 20 reports describing the event, only two (10%) identified mechanical problems with the radio. In one case, the pilot accidentally turned the radio off. In six cases, the pilots apparently transferred to the wrong frequency, including four cases that occurred after a correct readback of the frequency. (Note that if the incorrect frequency had been immediately detected by the controller or pilot, it would not have likely resulted in a PD). Ten reports described situations in which the pilot did not acknowledge the controller's instruction to change frequencies. In seven of these, the pilot stated that they never heard the instruction (with no report of radio or reception problems).

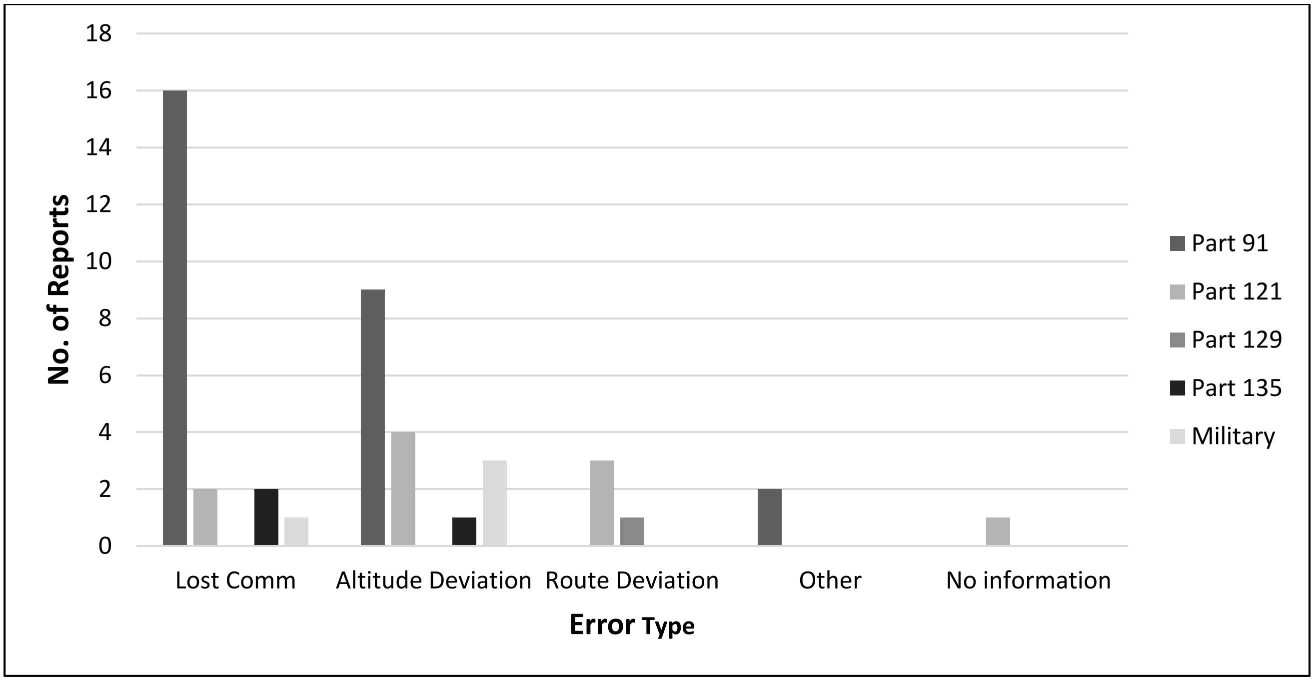

Figure 9. Number of PDs by Error Type and Type of Operation.

Fifteen of the 21 reports with a loss of communication event included an estimated duration. As shown in Table 2, the mean estimated loss of communication time was 41 minutes. Note, as with the previous analysis (Cardosi & Lennertz, 2017), the estimated duration only includes when the controller was *aware* of the lost communication, so the durations are probably underestimated.

Table 2. Duration (in minutes) of losses of communication.

	Duration
Mean	41
Standard Deviation	15
Median	38
Maximum	72
Minimum	15

Mechanical problems with radios and radio frequency coverage can present challenges to maintaining communication between aircraft and ATC. However, most losses of communication occur, or are discovered, upon transfer of communication from one controller to another. Transfer of communication as the aircraft transitions from sector to sector presents several vulnerabilities in maintaining communication between the aircraft and ATC. In fact, in a study of readback errors in the en route environment, 41% of all readback errors were associated with radio frequencies (Cardosi, 1993).

Several pilot and controller errors can result in a lost communication event:

- Controller forgot to assign new frequency;
- Controller assigned the wrong frequency;

- Pilot has radio volume set too low;
- Pilot accidentally turned radio off;
- Pilot readback the wrong frequency and the controller failed to notice the discrepancy;
- Pilot misdialed the frequency into the frequency selector;
- Pilot selected wrong radio; and
- Pilot was distracted and forgot to switch frequencies.

While many of these vulnerabilities will still be present with the use of CPDLC, the fact that the assigned frequency is easily retrievable by both the pilot and controller, and the availability of the CONTACT message, would be expected to significantly reduce the time required to regain voice contact with the aircraft.

Of the 21 lost communications PDs, CPDLC was identified as a potential mitigation in all but one incident in which the pilot fell asleep. The use of CPDLC is expected to help to prevent a loss of communications (if only by providing a reference to the correct frequency) and help to re-establish contact with the aircraft with a CONTACT message or by allowing the pilot to query the correct frequency. The following pilot statement exemplifies the time and workload that would have been saved if CPDLC had been available.

> …AC123 was cruising level at FL450 and communicating with Kansas City Center. I was the designated pilot-in-command for the trip and the pilot flying. A normal operating practice enroute is to do a radio check with center or any other controlling agency after a period of 15 minutes or so elapses without contact to make sure that there is not a loss of communication. When that occurred, we decided to do just that. When no reply was received, we realized that we were out of radio range for that frequency. We then pulled out the enroute chart and based on our position, determined that we had passed into Chicago Center's airspace. We found the list of center frequencies that was printed on the chart and began to call the center on one frequency at a time. After trying about six of the center frequencies without success, we called Chicago flight watch on the designated high altitude frequency. Once contact was established with them, we asked if they had a good frequency for the center based on our current position. They suggested a frequency which we then tried without success. I then asked the pilot not flying to try to contact center on the emergency frequency-121.5 mhz. Just as we were going to call on 121.5 mhz, we received a message from our dispatch telling us Chicago Center was trying to reach us on a particular frequency. We dialed in the appropriate frequency and established contact with Chicago Center. The rest of the flight continued without further issues.

(PCECZKC14007)

Altitude Deviations

Seventeen (40%) of the PDs in this data set involved altitude deviations. Four of these 17 deviations involved Part 121 operations, three involved military operations, one involved Part 135 operations and the rest involved Part 91 operations. As mentioned above, two events involved a loss of communication discovered after the aircraft descended below its cleared altitude; both of these events involved Part 91 operations.

Only two reports had no details regarding the causal or coincident factors involved in the aircraft climbing above, or descending below, the cleared altitude. The most commonly cited nature of the error (cited in 18% of the altitude deviations) involved the pilot flying the altitude in the flight plan, rather than an amended or newly assigned altitude. Two (12%) of the deviations were attributed to incorrectly set altimeters.

There were two anomalous situations (unlikely to reoccur): one was attributed to faulty flight plan information in FMC database; in the other, the altitude selector malfunctioned and 'jumped' after being set. (The same problem had been noted by another pilot and the equipment was subsequently replaced.)

The remaining altitude deviations were identified as being associated with common error threads, such as communication errors, expectations and distractions. Each of the following circumstances were involved in one of the remaining events:

Communication Error

- Pilot readback altitude incorrectly and controller failed to correct the error (readback/hearback error)

Expectation-related

- Pilot descended through assigned altitude after being asked, "If I give you lower…"
- Pilot climbed after being told to "Standby for higher"
- Pilot mistook an assigned heading for an altitude clearance

Memory

- Pilot failed to comply with a "Stop climb at [altitude]" instruction

Distraction

- Pilot stated he was hand flying and climbed through assigned altitude while looking for a traffic point out (assumption is that he was accustomed to the autopilot leveling off at the assigned altitude)
- Pilot overshot assigned altitude after a correct readback while distracted by electrical problems

In the majority (78%) of the altitude deviation reports, the use of CPDLC to transmit loadable altitude clearances would have helped to preclude the altitude deviation. The four events that were judged not to have been able to be precluded with the use of CPDLC were the two attributed to an incorrectly set altimeter, the deviation attributed to faulty information in the FMC database, and the event involving a "stop climb" instruction (since this is not a message that will be used en route).

Route Deviations

Of the four route deviations in the data set, three involved Part 121 operations and were attributed to errors (manually) loading the route into the FMC. The fourth event was an anomaly involving an error in the database used to construct the flight plan for a Part 129 operation.

Other Deviations

One deviation involved a pilot who did not recognize that he was entering controlled airspace. Another deviation involved an aircraft that turned in the wrong direction for traffic.

Mitigation with CPDLC

An examination of the nature of the errors suggested that the use of CPDLC could have mitigated the deviation in 77% (36 out of 43) of the reported incidents. CPDLC provides an easily accessible record of the frequency assigned and an additional means for the controller to contact the pilot (or vice versa). The ability to process altitude and route clearances with "loadable" clearances (i.e., able to be transferred into the FMC and potentially the mode control panel with a minimal amount of data entry) will help to reduce data entry errors.

3. Conclusions and Recommendations

The most common type of MOR related to human error involved a loss of controller-pilot communications. The most common controller error contributing to such events was the controller forgetting to assign a frequency upon transferring the aircraft to the next sector. Other controller errors contributing to lost communication events were issuing an incorrect frequency upon the transfer and failing to detect and correct pilot readback errors. The most common pilot errors contributing to lost communication events were not responding to an ATC transfer of communication and errors in hearing or setting the frequency. These types of errors are relatively common and would be expected to continue to be observed, although less frequently and for a shorter duration with increased transfer of communication via CPDLC.

The most common causes of validated losses of standard separation were the controller issuing a clearance that resulted in the conflict, misapplication of visual separation, and pilots climbing or descending through their assigned altitude. The reasons for altitude deviations were varied, with the most common being the pilot flying the altitude in the flight plan instead of the assigned (amended) altitude. The number and distribution of pilot and controller errors in this data set will contribute to a pre-implementation baseline to compare to post-implementation measures. This comparison will help to ensure that projected benefits have been realized and no unintended sources of error have been introduced with the implementation of CPDLC.

Overall, 84% of the PDs were determined to likely have been mitigated if the clearances had been transmitted via CPDLC, either with loadable altitude or route clearances or by virtue of being able to send a CONTACT instruction. The actual proportion of errors that could be mitigated will depend on level of equipage, proper usage, and assumes that both the air and ground systems are designed to minimize human error and ensure that errors are easy to detect and correct.

It should be noted that aside from NORDO aircraft, MORs are only generated when an event is significant enough to warrant a pilot deviation investigation, an operational deviation on the part of ATC, a loss of separation, or an emergency situation. There are many more instances of pilots and controllers misunderstanding altitudes/speeds/headings and routings that are immediately corrected, resulting in increased workload and frequency occupancy, but not a reportable adverse event. Any decrease in these unreportable errors would not only help to decrease the number of reportable events, but also help to decrease workload and frequency congestion.

A post-implementation analysis of MORs, validated losses of separation, and PDs will be needed to compare to the analysis presented here. (An analysis of EORs is not necessary, since only 8 of the 9619 reports in the present analysis contained useful information not already included in other reports.) Another potential source of useful information for the post-implementation error analysis is reports submitted to the Aviation Safety Assurance Program (ASAP). One of the FAA PD reports referenced an ASAP report number without identifying the nature of the error. Five other reports referenced that an ASAP report had been filed, but contained sufficient information to identify the nature of the error (e.g., lost communication or altitude deviation). Since the ASAP reports likely contain much more information on the causal and contributing factors that led up to the resulting error, they will be a fruitful source of information for the post-implementation analysis.

Finally, it should be noted that pre-and post-implementation comparisons will not be independently conclusive and will need to be interpreted in the context of other information. It is likely that the implementation of en route CPDLC will not be the only change in the National Airspace System that occurs in the interim. Any other changes (such as airspace or procedural changes) will also need to be considered in interpreting the results.

4. References

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