Flightcrew Procedures for Controller Pilot Data Link Communications (CPDLC)

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It is imperative that flightcrew procedures be developed and implemented to capitalize on the strengths of Controller Pilot Data Link Communications (CPDLC) while minimizing the possibility of error. This paper presents a sample of air carrier Standard Operating Procedures (SOPs) for the processing of ATC instructions transmitted via CPDLC. With CPDLC, it is recommended both crewmembers silently and independently read each CPDLC clearance, and confer before maneuvering the aircraft based on that clearance. This procedure allows the same independent interpretation that voice affords. A review of SOPS across seven carriers found that only one carrier instructed their flightcrews to follow this "silent read" procedure. Two carriers suggested that the message should be read out loud on the flight deck; four carriers did not specify a procedure. The methods for training on CPDLC procedures and specific topics covered also varied by air carrier. Based on the review of these materials "best practice" recommendations are provided.

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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		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		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	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	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		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
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/m^2	$candela/m^2$	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/in^2

*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)

Contents

List of Tables

Acronyms and Abbreviations

ATC	Air Traffic Control
CBT	Computer-Based Training
CPDLC	Controller Pilot Data Link Communications
Data Comm	Data Communications
DCL	Departure Clearance
FAA	Federal Aviation Administration
FMS	Flight Management System
FOM	Flight Operations Manual
GOLD	Global Operational Data Link Manual
ICAO	International Civil Aviation Organization
IFALPA	International Federation of Air Line Pilots' Association
MCP	Mode Control Panel
MEL	Minimum Equipment List
OJT	On the Job
PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management
PF	Pilot Flying
PM	Pilot Monitoring
SC	Special Committee
SOP	Standard Operating Procedure
WG	Working Group
WILCO	Will Comply

Preface

This report was prepared by the Aviation Human Factors Division of the Center for Safety Management and Human Factors at the John A. Volpe National Transportation Systems Center (Volpe Center). It was completed with funding from the Federal Aviation Administration (FAA) Human Factors Division (ANG-C1) in support of the Flight Standards Service, Flight Technologies and Procedures Division, Performance Based Flight Systems Branch (AFS-470). We would like to thank our FAA Program Managers, Tom McCloy, Ph.D. and Sherry Chappell, Ph.D., for their guidance and comments on a previous draft and our technical sponsors, Mark Patterson and Mark Steinbicker (AFS-470).

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Executive Summary

Given the fundamental differences between transmissions of Air Traffic Control Clearances (ATC) via voice and transmissions via Controller Pilot Data Link Communications (CPDLC), it is imperative that flightcrew procedures be developed and implemented to capitalize on the strengths of CPDLC while minimizing the possibility of error. This paper presents a sample of air carrier Standard Operating Procedures (SOPs) for the processing of ATC instructions transmitted via CPDLC. Unlike with voice instructions, with CPDLC, both crewmembers cannot hear the clearance simultaneously from ATC and form their own independent interpretation. Consequently, with CPDLC, it is recommended both crewmembers silently and independently read each CPDLC clearance, and confer before maneuvering the aircraft based on that clearance. This procedure allows the same independent interpretation that voice affords: If one pilot were to read the message out loud, the second pilot would be vulnerable to also "reading" what the first pilot read aloud and missing any discrepancies between what was heard and the written clearance. Similar guidance is provided in the International Civil Aviation Organization (ICAO) Global Operational Data Link Manual (GOLD). A review of SOPs across seven carriers (including both domestic and international) found that only one carrier instructed their flightcrews to follow this "silent read" procedure. Two carriers suggested that the message should be read out loud by the Pilot Monitoring (PM) and verified by the Pilot Flying (PF). Four of the seven carriers did not specify a procedure.

The methods for training on CPDLC procedures also varied by air carrier – the most common method of training was via independent study of the Flight Operations Manual (FOM). The topics covered in training also varied widely, including descriptions of how to log on to CPDLC on the aircraft, how to load clearance information on the flight deck, how to respond to messages, and guidance on the use of multi-element messages and free text.

Based on the review of these materials, "best practice" recommendations are provided (a stand-alone summary of best practices is provided in Appendix C). We suggest that flightcrew SOPs should include the silent read procedure, tailored to different operating environments. Best practices for preventing communication errors between pilots and ATC and within the flightcrew are also provided.

1. Introduction

There are several fundamental differences between transmissions of Air Traffic Control (ATC) clearances over voice and transmissions via Controller Pilot Data Link Communications (CPDLC). Voice communications are fast, but transient (that is, when the controller finishes the transmission, the opportunity to process that message is over); CPDLC are more persistent, but more time consuming. The pilot can refer to a single CPDLC transmission as often as needed, but the message requires more time to access than does recognizing one's call sign on the voice frequency. CPDLC also precludes the possibility of a pilot erroneously accepting a clearance intended for another aircraft by misidentifying the call sign. It is critical that flightcrew procedures be developed and implemented to capitalize on the strengths of CPDLC while minimizing the probability of error due to differences between CPDLC and voice.

This work was intended to sample air carrier Standard Operating Procedures (SOPs) for the processing of ATC instructions transmitted via CPDLC. Where no company SOP was stated, the relevant training materials regarding the handling of CPDLC clearances are described. This information was gleaned from Flight Operations Manuals (FOMs), training materials, and company safety bulletins. The materials were not intended to be exhaustive by carrier, but rather a sampling by carrier of training that an individual pilot would receive. Since much of this material is fleet specific, a pilot of one type aircraft could receive more, or slightly different, information than the pilot of another type aircraft within the same carrier, if the carrier's procedures for CPDLC are presented solely in FOMs.

CPDLC materials from seven airlines were reviewed. Of these, three airlines were Part 129 (foreign) carriers, and four were Part 121 (domestic) carriers. Currently, CPDLC is primarily used in oceanic airspace and international operations (with the exception of Departure Clearance [DCL] service), which is currently implemented at a few domestic airports. Therefore, the majority of materials reviewed were intended for pilots who fly internationally.

In addition to sampling guidance provided by air carriers to their flightcrews, recommendations for best practices offered by industry groups are also described. Some of the best guidance material, from a human factors perspective, is contained in the International Civil Aviation Organization (ICAO) Global Operational Data Link (GOLD) Manual, the Safety Bulletin published by the International Federation of Air Line Pilots' Association (IFALPA, 2011), and the material being developed by the Data Comm Implementation Team (DCIT). These materials offer specific recommendations designed to minimize crew errors and would be beneficial to all pilots who use CPDLC.

As CPDLC is implemented for domestic operations in the US, training will need to be expanded. This will present an opportunity to promulgate more standardization in the procedures and materials proffered to flightcrews. Specific suggestions for such training are offered in Section 4 of this paper.

2. Flightcrew Procedures for CPDLC Messages

Cross-verification is a critical safety net in flight operations. For example, the most basic of safety nets – the checklist – is completed and verified with participation from both crewmembers. A significant reduction in "altitude busts" was credited to the introduction of a procedure in which one pilot would readback an altitude clearance while entering it into the Mode Control Panel (MCP), while the other pilot verified that the correct altitude was entered by pointing to it; this insures a common understanding of the altitude clearance between both pilots and that the correct (or at least commonly understood) altitude is entered on the flight deck. It is this safety net of a common crew understanding of the correct clearance that needs to be carried into the future Data Comm environment.

One key difference between voice communications and CPDLC is that voice transmissions offer both crewmembers the opportunity to simultaneously hear the clearance and independently form their own interpretation. With CPDLC, the message may need to be accessed before it can be viewed (i.e., via one or more button presses), and it may not be convenient or appropriate for both pilots to read it at the same time. To ensure a common understanding of all clearances, it is recommended that both crewmembers silently and individually read each CPDLC clearance and then confer before maneuvering the aircraft to comply with the clearance; this validation part of the procedure ensures that both crewmembers have the same independent interpretation that voice affords. If one pilot were to read the clearance aloud before (or while) the second pilot reads it, the second pilot would be vulnerable to "reading" what the other pilot read aloud and missing any discrepancies between the actual clearance and what was heard. This silent read can be accomplished simultaneously or sequentially, depending on factors such as the equipment available and other concurrent duties. This procedure for crew verification of a data link clearance is commonly referred to as the "silent read" or GOLD procedure, since it was published as a recommended SOP in the GOLD:

> "To minimize errors, when responding to a clearance with WILCO, each flight crew member should read the uplink [i.e., messages sent from ATC to flight crew] message individually (silently) before initiating a discussion about whether and how to act on the message. Reading a message individually is a key element to ensuring that each flight crew member does not infer any preconceived intent different from what is intended or appropriate. Use of this method can provide a flight crew with an acceptable level of situational awareness for the intended operations."
>
> (4.1.2.5, ICAO GOLD, anticipated 2016; text in brackets added)

> "When a CPDLC uplink is received, each flight crew member (e.g. pilot flying and pilot monitoring) should read the message from the flight deck displays individually to ensure situational awareness is maintained. Once the message has been individually read, the flight crew should then discuss whether to respond to the message with DM 0 WILCO or ROGER, as appropriate, or UNABLE."
>
> (4.3.1.1, ICAO GOLD, anticipated 2016)

Additional relevant guidance from the GOLD is shown in Appendix A. Similar guidance is offered in EUROCONTROL's Flight Crew Data Link Operational Guidance shown in Appendix B. Additional information is also contained in AC120-70C (*Operational Authorization Process for Use of Data Link Communication System*, FAA, 2010).

As can be seen in Table 1, procedures for processing an uplink message differ by carrier. Only one carrier explicitly specifies the procedure recommended in the GOLD. Specifically, both the Pilot Monitoring (PM) and the Pilot Flying (PF) are to silently and independently read the message. Then, the flightcrew members discuss and evaluate the message. The PM then loads the instruction into the Flight Management System (FMS). Both pilots verify the information, the PM sends the appropriate response back to ATC (e.g., ACCEPT, REJECT) and the PF complies with the clearance. Another carrier referred their pilots to the GOLD for guidance material, but did not specify any company SOP. Three airlines explicitly specified that the flightcrew should only execute an instruction *after* an "ACCEPT" or "WILCO" reply is sent to ATC.

Table 1. Flightcrew procedures for CPDLC message by Carrier.

	"Read Aloud" Procedure	"Silent Read" Procedure	No procedure specified
Carrier 1 (Part 129)	✓		
Carrier 2 (Part 129)			✓
Carrier 3 (Part 129)			✓
Carrier 4 (Part 121)		✓	
Carrier 5 (Part 121)			✓
Carrier 6 (Part 121)			✓
Carrier 7 (Part 121)	✓		

Surprisingly, two of the airlines sampled (one Part 121 and one Part 129 carrier) instruct their

flightcrews to have the Pilot Monitoring (PM) read the message aloud to the Pilot Flying (PF). The PF is then to verify the content of the message (e.g., by reading the message silently on the display). The PM responds to the message (e.g., ACCEPT, REJECT), while the PF executes the instruction. The intent of such a procedure is to attempt to mimic the safety net inherent in verbal ATC communications in that both pilots have the opportunity to hear the message at the same time. In reality, however, having the PM read the message aloud reduces the PF's chances of detecting an error in the PM's interpretation. While it would be acceptable to have the PM point out that an altitude clearance was received, for example, reading the altitude clearance aloud is ill-advised. If the PM were to misread the altitude, the PF would likely see what was read to him/her, rather than what is actually displayed, since we all have a tendency to see what we expect to see. Furthermore, some pilots may confuse independent verification of the message with both pilots pointing to their display of the entered information. For example, having both pilots silently read and then confer on an altitude clearance is different than, but equally important as, having both pilots point to the altitudes entered into the MCP. Pointing to the entered altitudes only fulfills the CPDLC verification check if the altitudes are independently entered based on the silent read and then the two are matched and verbally identified.

One carrier advises flightcrews to print every message prior to reviewing it and then store the printed messages in the order in which they were received. The carrier's materials reviewed for the purposes of this study did not include information on potential differences between the displayed and printed message or dictate that the clearance be read on the display to verify the printed version.

3. Training for CPDLC Procedures

3.1 Methods of Training

Just as the CPDLC procedures vary widely among air carriers, so do the methods by which pilots are trained to use CPDLC. Training vehicles include:

- On-the-Job Training (OJT) on revenue flights (with or without a check airman),
- A brief (one or two page) flight bulletin,
- Material included in the FOM,
- Incorporation of company SOPs into simulator training.

The results of the sampling of training methods for the carriers reviewed are presented in Table 2. The most limited flightcrew training for CPDLC is, in effect, no training. That is, pilots can be expected to read material (such as the FOM) on their own and learn as they go. Indeed, personal communications with pilots from two carriers (both Part 129) said that training for CPDLC procedures occurs only on the line and that flightcrews are expected to learn through their own experience.

Table 2. Type of CPDLC Training by Airline.

	On the Job	Flight Bulletin	Refers to GOLD	Flight Operations Manual	Computer -Based Training	Classroom Training	Simulator Training
Carrier 1 (Part 129)	✓			✓			
Carrier 2 (Part 129)	✓		✓	✓			
Carrier 3 (Part 129)	✓						
Carrier 4 (Part 121)		✓		✓	✓		✓
Carrier 5 (Part 121)		✓		✓	✓		
Carrier 6 (Part 121)				✓			
Carrier 7 (Part 121)			✓	✓		✓	✓

3.2 Specific Training Topics

The topics covered in the bulletins and FOMs varied widely, from just the basic mechanics – such as how to log on and accept or reject a message – to detailed material on when to use CPDLC (vs. voice), and how to minimize the risk of communication errors, both between the flightcrew and ATC and within a flightcrew. This section reviews the topics covered in printed materials (company bulletins and FOMs) in more detail.

3.2.1 Log On

The most basic of CPDLC procedures involve the mechanics of log on. Three airlines provided similar guidance for CPDLC logon procedures–specifically that the flight number used to logon must *exactly* match the flight number on the ICAO flight plan (e.g., the same number of leading zeros). Two of these airlines explicitly state that the flightcrew should revert to voice if any difficulties are experienced.

3.2.2 Display of large messages

Large messages, which often contain loadable route information, cannot be shown in their entirety on the message display. Two of the airlines reviewed provide the flightcrew with guidance on the additional steps (e.g., button presses) that are needed to review a large and/or loadable message, and one of these airlines further suggests that large messages can be reviewed in their entirety when printed.

3.2.3 Display of response options

One carrier specifies that response options (i.e., ACCEPT, REJECT) are only shown after all message pages have been reviewed (to help ensure that flightcrews see the entire message before replying). [Note: Since designs differ, this cannot be said of every flight deck implementation.] The same carrier also describes for their pilots how a flightcrew's response of "ACCEPT" or "REJECT" translates (i.e., to WILCO, ROGER, AFFIRMATIVE or UNABLE, NEGATIVE) depending on the content of the message.

3.2.4 Use of "STANDBY"

Two of the carriers provided their pilots with information on the use of "STANDBY". One (Part 121 carrier) informs pilots that if ATC responds with "STANDBY", they can expect a response within 10 minutes. If a response is not received within 10 minutes, pilots are instructed to send an inquiry to ATC (such as "when can we expect") but not to duplicate the request.

Another carrier (Part 129) provides similar information as above, but adds that if a delay of more than 10 minutes is anticipated, ATC will reply with "REQUEST DEFERRED". They also give pilots useful information on the transmission times for CPDLC messages, explaining that it can take up to one minute for a controller to receive the pilot request and another minute for the pilot to receive the controller response. The same carrier also informs the pilots as to when they should reply to ATC with "STANDBY". They instruct pilots to use the "STANDBY" response when there will be a short (up to 10 minute) delay before they can send a response and that a subsequent "ACCEPT" or "REJECT" response will need to follow to close the exchange.

3.2.5 Loadable information

One Part 121 carrier describes a safeguard on the flight deck to help ensure that information is loaded correctly on the MCP: a correct entry (e.g., speed, heading, altitude) changes from white to green on the display. Both pilots are also instructed to double check information that is loaded on the flight deck through pointing to and verbalizing the information.

3.2.6 Use of the message log

Two airlines described the use of the message log on the flight deck. One airline specified that CPDLC

messages can be reviewed using the log, with the most recent message at the top of the log. Another airline provided details on the function of the message log, in particular, that 1) it can hold up to 75 messages, 2) older messages are automatically deleted once the log is full, *or* new messages cannot be accepted, 3) the message log is typically cleared out after each flight.

3.2.7 Conditional clearances

Conditional clearances, such as those that instruct a flightcrew to act "AT" or "BY" a particular time or position, merit special attention. IFALPA (2011) developed a safety bulletin to caution pilots on their use, but no similar guidance was found in any of the carrier-specific material.

3.2.8 Complex messages

Two airlines make reference to messages with more than one element (i.e., multi-element or concatenated messages). One airline simply specifies that a single message can have up to 5 elements; another carrier suggests that multi-element messages should be avoided due to the possible confusion they can cause and because the entire message will be rejected if any component is rejected.

3.2.9 Downlink messages

Three of the airlines reviewed provided specific guidance on downlink messages (i.e., messages sent from the flightcrew to ATC) and how flightcrews can use them to request or provide specific information to ATC. These airlines typically mentioned that downlinks are categorized as reports (e.g., position reports), requests (including "when can we expect") and responses.

Three airlines also provided some guidance on how to interact with ATC regarding an open request, and mentioned that the same request should not be resent. Two of these airlines instructed flightcrews to follow up on a request using a "when can we expect" message – as this will avoid having two identical open messages. One airline instructed flightcrews to follow up using a free text message. One airline further specified that a response is typically received from ATC within two minutes however ATC may send a "STANDBY" response if more time is required to assess the downlink. In these instances, the flightcrew should wait 10 minutes before sending an inquiry (not a duplicated message).

3.2.10 Use of free text to compose messages

Three of the airlines reviewed provided guidance on the use of free text messages (i.e., when the whole message must be manually typed – not to be confused with pre-formatted free text messages where the flightcrew "fills in the blanks") – in general, free text messages should be avoided and used only when necessary, such as when a standard message element does not exist. Each of these airlines provided additional rationale on why free text messages should be avoided. For example, free text messages may not use standard phraseology and cannot be loaded in the FMS. Another airline specified that ATC

cannot use a standard response to reply to a free text message, and that free text messages may be problematic for ground automation.

4. Recommendations

With the planned implementation of CPDLC in domestic en route airspace, airlines will need to add or revise their current CPDLC training and materials. This will provide an opportunity to ensure that pilots are availed not only of the basics of how to use CPDLC, but information that will inform them as to when to use CPDLC (vs. voice) and ways to help prevent miscommunications. It will also provide an opportunity to ensure SOPs are in place for reviewing and responding to an incoming CPDLC message.

4.1 Use of a printer

Many flight decks have a printer available. As previously described, one carrier prescribes how it should be used. In some implementations, an uplink cannot display the entire routing until it is loaded or printed. However, printers may not produce an exact replica of the message on the flight deck display. For example, it can print pages out of order or fail to print the last page. Moreover, flight deck printers are not certified or part of the Minimum Equipment List (MEL). Therefore, even if the message is printed, it must still be reviewed on the primary flight deck display approved for that purpose before the message is used.

4.2 Multi-element messages

Just as with voice transmissions, a single CPDLC transmission can contain multiple elements, such as an altitude clearance and a speed restriction. Unlike voice, with CPDLC pilots cannot accept one clearance in the transmission and reject another. Pilots must respond “UNABLE” to any CPDLC transmission that contains an instruction that cannot be executed or a restriction that cannot be met.

4.3 “Expect” messages

The individual-silent read procedure for all clearances before maneuvering the aircraft may also help to prevent flightcrews from erroneously acting on “EXPECT” messages—in these cases, the flightcrew may request a particular attitude, in which ATC responds, “UNABLE, MAINTAIN [current flight level], EXPECT [a different flight level]” – here, the flightcrew may see what they expect to see (their requested flight level), and erroneously maneuver to it. Note, in the recently published RTCA Special Committee (SC) 214/EUROCAE Working Group (WG)-78 message set (i.e., RTCA DO-350, 2014), the uplink message “EXPECT [level]” has been revised to “EXPECT [higher/lower]” to help prevent such errors.

4.4 Conditional clearances

Conditional clearances can only be executed after a condition is met. The problems with conditional clearances containing “AT” and “BY” have long been noted by both the United Kingdom and Portugal. As a result, Shanwick no longer uses conditional clearances containing start point restrictions (except by voice). Recently, the United Kingdom presented a paper within the ICAO North Atlantic Air Traffic Management Group (NAT ATMG/35, WP/18, 2010) that states: “Despite strenuous efforts over recent years to clarify the meaning of the terms “AT” and “BY” in CPDLC uplink messages, incidents continue to be caused by flight crew misinterpretation of ATC conditional climb/descent clearances.” The paper gives several examples in which the pilot climbed late when given an instruction to “CLIMB TO REACH [level] BY [position]”. They note that “level change messages with a restriction to be level by a particular time do not appear to create the same level of ambiguity”. At the same meeting, Portugal presented a similar paper, “Use of AT and BY in CPDLC messages” (NAT ATMG/35, WP/22, 2010). This paper also discusses problems experienced with CLIMB/DESCEND TO REACH [altitude] BY [position].

Operational experience has found that a common error is for pilots to miss the condition (i.e., the word “AT”) and climb/descend immediately rather than wait until the condition is satisfied. The silent and individual read, confer, and then execute procedure helps mitigate against these errors. When both pilots silently and individually read the clearance, the second pilot has the opportunity to catch an error that the first pilot may have made. Again, if one flightcrew member reads the clearance aloud, it will be more difficult for the second crewmember to catch any errors because he/she will then be primed to read exactly what was just heard. It is also important to note that the RTCA SC-214/EUROCAE WG-78 CPDLC message set (RTCA DO-350, 2014) includes several improvements to help prevent the flightcrew from acting erroneously on these clearances, including a change in phraseology (e.g., “BEFORE PASSING” instead of “BY”) and making the condition more visible (e.g., “AT TIME [time]” instead of “AT [time]”).

The word “BY” can be easily misconstrued with reference to a position, particularly by non-native English speakers. In other languages, as in English, the word “by” has a number of different meanings including “via” (by way of) and “along side of”. This could explain why the predominant error noted in Europe is that the pilot does not start the maneuver (usually a climb) in time to reach the altitude before the position. It also helps to explain why “BY [position]” seems to be more problematic than “BY [time]”. The more likely explanation for these instances, as well as the majority of the errors involved with the conditional clearances containing “AT”, is that pilots are seeing the clearance they expect to see. It should be noted that conditional clearances are not scheduled to be implemented in US en route airspace. Still, pilots will need to guard against seeing the clearance that they have requested.

4.5 Use of CPDLC in specific operating environments

Company SOPs should be developed for accepting and executing a CPDLC message in different operational environments. These procedures would be expected to vary by airline and fleet to accommodate a mixture of corporate cultures and equipment. They would identify the appropriate roles

of the PF and the PM for executing various types of clearances in different operating environments, to ensure the maximum protection against pilot error while being appropriate for the tempo of the operations. Recommended practices for different operating environments are presented below. These recommendations are based on previous research conducted on errors in CPDLC communications (e.g., EUROCONTROL, 2012; IFALPA, 2011), best practices identified in the GOLD, and known human factors principles.

4.5.1 Oceanic airspace

In the *oceanic environment*, the silent and individual read, confer, then execute procedure is recommended for all ATC messages. During this period, workload is relatively low and there is ample time to accommodate this procedure. In some situations, the flightcrew may require additional time to read and confer about a CPDLC message, especially if there are other higher-priority tasks. In this case, the flightcrew should respond with "STANDBY". This guidance is echoed in the GOLD, the flightcrew should respond to CPDLC messages "as soon as practical after they are received…the flight crew should not be pressured to respond without taking adequate time to fully understand the CPDLC message. If additional time is needed, the flight crew should send a STANDBY response" (4.3.2.4, ICAO GOLD, anticipated 2016).

4.5.2 En route airspace

In *the en route environment,* it may or may not be feasible for both pilots to silently read each CPDLC message and then confer. The tempo of the operations and concomitant flightcrew workload will determine the degree to which this is appropriate. For simple messages that do not change the trajectory of the aircraft, the verification is less critical than for control messages. In no case, however, should one pilot simply read and execute the clearance or read it to the other pilot to execute. Both pilots need to have an independent understanding of the clearance before it is executed. Both pilots should be on the watch for conditional clearances and EXPECT messages to ensure appropriate action. Note that, in line with the "sterile cockpit rule", CPDLC messages should typically not be sent or received below 10,000 feet unless they are critical to the safety of the flight.

4.5.3 On the ground

On the ground at the gate or in a **non-movement area**, both crewmembers should review the departure clearance or revised departure clearance. This could be accomplished by one crewmember programming the clearance into the FMS and having the other crewmember review it. The flightcrew should not depart from the gate until the initial departure clearance and any subsequent revised departure clearances are verified and accepted by both crewmembers.

After departing the gate, it is possible that the flightcrew may receive a revised departure clearance while taxiing in an **ATC-controlled movement area**. The flightcrew should act in accordance with

company policy or best operational judgment to review and respond to the revised clearance in a timely manner. While in this area, and especially if near an active runway, both crewmembers should be heads up—looking out the window. Company SOPs should reflect crew coordination when operating in a high-tempo area where the flightcrew is changing the trajectory of the aircraft while taxiing, for example, while turning the aircraft to hold short of a runway, or transitioning between different taxiways. To help prevent runway incursions, heads-down activities should not be conducted in close proximity to an active runway. Simple revisions (such as a change in transponder code or initial altitude) that require minimal heads-down time and distraction may be accomplished while taxiing. More complex revisions, which require significant heads-down time, should not be performed while taxiing near an active runway. These activities should be limited to areas where there is minimal ground traffic and sufficient taxi distance or where known traffic delays exist prior to takeoff (allowing sufficient time for the PM to enter the route information with the PF monitoring and confirming the revised route information).

Revised departure clearances, such as those involving a runway change or a full re-route, may require substantial heads-down time for FMS route loading and verification. Whether or not these activities can be conducted without requesting additional time from ATC will depend on a variety of factors. In some cases, it may not be prudent to conduct these activities when the aircraft is in motion. It is advisable to notify the appropriate ATC controller (ground or tower control) and pull out of the ground traffic flow in areas of high-density traffic or high-tempo operations, in low-visibility or complex operations, or under any other conditions that are dictated by safety.

5. Summary of Recommendations

5.1 Procedures

- Each crewmember should silently and individually read each CPDLC message and then confer, whenever feasible, and at a minimum, before execution of a control instruction.
- Printers, when available, should not be used as the primary means of reading the CPDLC clearance. Printed CPDLC messages should always be verified against the primary display before use.
- A multi-element message may contain more than one instruction. Pilots must respond “UNABLE” to any CPDLC transmission that contains a clearance that cannot be executed or a restriction that cannot be met.

5.2 Highlights for Training

- CPDLC messages may be more than one page in length. Some, but not all, implementations do not allow the pilot to respond until after the last page has been displayed. Care must be taken to

ensure that the entire message is reviewed before a response is sent or an instruction is executed.

- An inquiry or an "expect" message from ATC should never be construed as a clearance. For example, "WHEN CAN YOU ACCEPT FL230?" does not constitute a clearance, even if it can be accepted immediately. Similarly, a response to "WHEN CAN WE EXPECT…?" does not constitute a clearance.
- Pilots need to be aware of the tempo of CPDLC communications (e.g., transmission times) and how it relates to air traffic operations. For example, the use of "STANDBY" is recommended in the oceanic environment whenever additional time is needed before pilots can respond to a message. In the en route environment, there will be times when a "STANDBY" response will not be operationally appropriate and the pilots should revert to voice. However, dialogs initiated on CPDLC need to be finished on CPDLC; the CPDLC dialog will need to be closed out with an "ACCEPT" or "REJECT" response, even if a verbal response has been given.
- Pilots should use standard messages that they can select from their message set whenever possible. Free text messages should only be used when necessary, such as when a standard message does not exist.
- Printers may not produce an exact replica of the message on the flight deck display. For example, it can print pages out of order or fail to print the last page. Even if the message is printed, it must still be reviewed on the primary flight deck display approved for that purpose before the message is used.
- Conditional clearances, such as those that instruct a flightcrew to act "AT" or "BY" a particular time or position, merit special attention – flightcrews should pay particular attention to any conditional clearance.

6. References

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IFALPA, *Safety Bulletin: Navigational errors on the North Atlantic*, September 30, 2011.

Portugal. (2010). *Use of AT and BY in CPDLC Messages,* WP/22, 03/04/2010, Presented at 35th Meeting of North Atlantic Air Traffic Management Group**,** Paris.

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Appendix A: Excerpts from the GOLD

4.1.2 Operational differences between voice communications and CPDLC

4.1.2.1 Development, testing, and operational experience have highlighted fundamental differences between voice communications and CPDLC. These differences need to be considered when developing or approving flight crew procedures involving the use of CPDLC.

4.1.2.2 For example, when using voice communications, each flight crew member hears an incoming or outgoing ATS transmission. With voice, the natural ability for each flight crew member to understand incoming and outgoing transmissions for their own aircraft has provided a certain level of situational awareness among the flight crew. With CPDLC, flight crew procedures need to ensure that the flight crew has an equivalent level of situational awareness associated with understanding the content and intent of a message in the same way.

4.1.2.3 Each flight crew member (e.g. pilot flying and pilot monitoring) should individually review each CPDLC uplink message prior to responding to and/or executing any clearance, and individually review each CPDLC downlink message prior to transmission.

4.1.2.4 If an operator uses augmented crews, the flight crew carrying out the “handover” briefing should thoroughly brief the “changeover” flight crew or flight crew member on the status of ADS-C and CPDLC connections and messages, including a review of any pertinent uplink and downlink CPDLC messages (e.g. conditional clearances).

4.1.2.5 Uplink messages require special attention to prevent the flight crew from responding to a clearance with DM 0 WILCO, but not complying with that clearance. To minimize errors, when responding to a clearance with DM 0 WILCO, each flight crew member should read the uplink message individually (silently) before initiating a discussion about whether and how to act on the message. Reading a message individually is a key element to ensuring that each flight crew member does not infer any preconceived intent different from what is intended or appropriate. Use of this method can provide a flight crew with an acceptable level of situational awareness for the intended operations.

4.1.2.6 In a similar manner, each flight crew member should individually review CPDLC downlink messages before the message is sent. Having one flight crew member (e.g. the pilot monitoring) input the message and having a different flight crew member (pilot flying) review the message before it is sent provides an adequate level of situational awareness comparable to or better than voice communication.

4.1.2.7 The flight crew should coordinate uplink and downlink messages using the appropriate flight deck displays. Unless otherwise authorized, the flight crew should not use printer-based information to verify CPDLC messages as printers are not usually intended for this specific purpose.

Note —For aircraft that have CPDLC message printing capabilities, there are constraints

associated with the use of the flight deck printer. Printers may not produce an exact copy of the displayed clearance with the required reliability, and should not be used as the primary display for CPDLC. However, in some cases, printed copies may assist the flight crew with clearances and other information that are displayed on more than one page, conditional clearances and crew handover briefings.

…

4.3.1 General

4.3.1.1 When a CPDLC uplink is received, each flight crew member (e.g. pilot flying and pilot monitoring) should read the message from the flight deck displays individually to ensure situational awareness is maintained. Once the message has been individually read, the flight crew should then discuss whether to respond to the message with DM 0 WILCO or DM 3 ROGER, as appropriate, or DM 1 UNABLE.

4.3.1.2 When processing an uplink multi-element message, the flight crew should ensure that the entire uplink has been read and understood in the correct sequence prior to responding.

Note —A CPDLC multi-element message is one that contains multiple clearances and/or instructions. The display may only show part of a CPDLC multi-element message and require flight crew interaction to see the entire message.

(Global Operational Data Link (GOLD) Manual, anticipated 2016)

Appendix B: Excerpts from Link2000+ Guidance

7.3.6 Flight Crew Team Situation Awareness

One advantage of voice communications is that both pilots are able to hear ATC messages and check to ensure that they both heard the same thing. With CPDLC, the Pilot Not Flying (PNF) is responsible for managing data link communications. However, to maintain the safety net of flight crew verification of ATC instructions, each pilot should read all "data linked" clearances (silently) before discussing the message and response.

When the Pilot Flying (PF) reads the clearance, it affords the same opportunity provided by voice communications for the PF and PNF to confer and ensure that their understanding of the clearance is the same. Having the PNF read the message *silently*, before the PF reads the clearance prevents the PNF from setting up an expectation bias. That is, if the PNF was to read the message aloud, the PF would likely "see" the clearance that he heard, making it more difficult to detect any discrepancy between the clearance that the PNF read and the one actually displayed. Independent assessment and verification of the message provides a strong safety net to trap errors. This safety net is critical to maintaining flight crew situation awareness and preventing pilots from executing an incorrect response, such as prematurely acting on a conditional clearance.

7.3.6.1 Recommendation:

Operational procedure design and training should include measures to ensure that the PF and PNF silently read all ATC clearances and then confer, before executing a clearance.

(LINK2000+/FLIGHT CREW DATA LINK OPERATIONAL GUIDANCE, version 5.0, 17 December 2012)

Appendix C: Flightcrew Procedures for CPDLC, Best Practices

When Air Traffic Control (ATC) issues an instruction over the radio, both crewmembers can hear the clearance. To preserve the same safety net when a clearance is received over CPDLC, both crewmembers need to have the same opportunity to *independently* identify the clearance. This means that both crewmembers need to silently read the clearance. The silent reading of the clearance ensures an independent interpretation; it prevents a pilot from "reading" what the other pilot read aloud and missing any discrepancies between what was read aloud and the actual clearance. The pilots then confer before maneuvering the aircraft. Depending on factors such as the equipment available on the aircraft and concurrent duties, both pilots can read the clearance at the same time or one after the other before conferring. Company SOPs will determine the roles of the Pilot Flying and Pilot Not Flying in this process, but in no case should one pilot simply read and execute the clearance or read it to the other pilot to execute.

Best practices for processing CPDLC clearances are tailored to different operational environments.

On the ground, departure clearances should be processed while at the gate or while the aircraft is stopped in the non-movement area. Ideally, the departure clearance would be entered and verified before pushback.

Simple **revisions of departure clearances** (such as a change in squawk code) that require minimal heads-down time and distraction can often be accomplished while taxiing. *(Note however, that to help prevent runway incursions, heads down activities should* **not** *be conducted while taxiing in close proximity to an active runway.)* As with other complex tasks, revised departure clearances that require substantial data entry (for example, those involving a runway change) should be processed while the aircraft is stationary with the parking brake set.

In the **domestic en route** environment, when service becomes available, flightcrew response time will need to be consistent with the operational tempo. Again, pilots should silently read the message and confer before maneuvering the aircraft. In most cases, the flightcrew will be able to respond to the message within one minute. If additional time is needed, the flightcrew should send a "STANDBY" response and send a closure response as soon as practical. In accordance with the "sterile cockpit rule", CPDLC messages will typically not be sent or received below 10,000 feet unless they are critical to the safety of the flight.

In the **oceanic environment**, the operational tempo is more relaxed than in the radar environment, but flightcrews are still expected to respond to messages as soon as practical. Again, both crewmembers should silently read the clearance, and confer before maneuvering the aircraft. The flightcrew should not feel pressured to respond without taking adequate time to fully understand the message and respond to other higher priority operational demands. If time is needed, the flightcrew should send a "STANDBY" response. If a "STANDBY" response has

been sent, the flightcrew should provide a subsequent closure response to the message within a reasonable period of time.

Conditional clearances. Conditional clearances require special attention by the flightcrew. A conditional clearance is an ATC clearance given to an aircraft with certain conditions or restrictions such as changing a flight level based on a time or place. An example of a conditional clearance is "AT [time] CLIMB TO [level]". Conditional clearances add to the operational efficiency of the airspace, for example, by allowing aircraft to be cleared at a later time to altitudes that are not immediately available. However, conditional clearances have been associated with a disproportionate number of pilot errors. Too often, pilots have executed the maneuver before the condition is met. Flightcrews need to exercise particular caution in executing conditional clearances and ensure that any conditional clearances are highlighted in briefings of augmented crews.

Use of Free text. Free text messages are to be used only when an appropriate standard message element does not exist. When composing a free text message, the flightcrew should use standard phraseology and format and avoid nonessential words and phrases. Abbreviations should only be included in free text messages when they are a part of standard ICAO phraseology.

Use of the printer. Printers may not produce an exact replica of the message on the flight deck display. For example, it can print pages out of order or fail to print the last page. Even if the message is printed, it must still be reviewed on the primary flight deck display approved for that purpose before the message is used.

Use of CPDLC for the transfer of messages between pilots and ATC reduces frequency congestion and offers many advantages over voice. The best practices outlined above help to minimize the risk of flightcrew error and ensure that system benefits are fully realized.

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