Flight Crew Cooperation during live Controller-Pilot Datalink Communication trials

Running head: Flight Crew Cooperation during live Controller-Pilot Datalink Communication trials

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Abstract

The empirical study reported here investigated the qualitative effects of the introduction of Controller-Pilot Datalink Communication (CPDLC) on intra-cockpit work. During a period of 11 months, line operations using datalink communication between the air traffic controller and the aircrafts in controller-pilot datalink Northern European airspace were observed to document the transformations of cockpit communications and coordinative patterns. Among the findings were that controller-pilot datalink easily takes precedence over other cockpit tasks, especially during higher-tempo operations; that controller-pilot datalink changes and erodes some of the redundancy previously inherent in receiving clearances by voice communication, and that it blurs the roles of pilot-flying and pilot-not-flying. In addition, the interface for controller-pilot datalink messages can interfere with the presentation of other flight-related data. Carriers wishing to introduce controller-pilot datalink need to carefully consider how to adapt cockpit procedures and pilot roles to datalink communication, in order to ensure that previously existing communication redundancy is not eroded away.

Introduction

New technology changes the task for which it was designed (Mokyr, 1990; Billings, 1997). While generally offering some quantitative system benefits (e.g. higher accuracy, greater capacity, lower manning requirements), the real effects new technology are qualitative—changing the work people do, altering knowledge and skill requirements, shifting communication patterns across new cognitive architectures (cf. Hutchins, 1996) and transforming the expressions of expertise and error.

The role of talk has long been deemed crucial in creating safety in aviation (e.g. Hawkins, 1993; Cushing, 1995) a realization recently accelerated through discoveries of conversation patterns at the micro-level (Nevile, 2004). The introduction of datalink (i.e. written communication mediated via a computer) communication between air traffic control and aircrew has the potential to fundamentally alter the role, use, robustness, frequency and patterns of talk both between the controller and aircrew and intra-cockpit. As with the introduction of most new technology in aviation and elsewhere, its real impact is generally poorly studied and ill-understood, creating the potential for unanticipated side-effects (e.g. Billings, 1997).

So far, datalink communication has been relied on for non-safety related information exchange, for example the Aircraft Communications Addressing and Reporting System (ACARS). Putative over-crowding of voice communication frequencies has spawned the development of other applications of air-ground datalink communication. One data link application is Controller-Pilot Data Link Communication (CPDLC) where datalink messages are shown as short text messages on a screen for the pilots and the air traffic controllers (ICAO, 1999). CPDLC, for the benefit of non-domain readers in this article written out as controller-pilot datalink enables the flight crew and controllers to exchange routine, non-time critical air traffic control related instructions, clearances and requests via data link text messages (Eurocontrol, 2005a). By transferring some communication between the controller and the aircraft from voice to datalink, the operational community expects benefits to Air Traffic Control efficiency, capacity and communications in order to accommodate the expected growth in air traffic demand. By reducing the time used for voice communication through less voice instructions and repetitions of misunderstood messages one controller would then be able to handle more traffic in his responsibility sector of the airspace (Eurocontrol, 2005b).

Voice radiotelephony relies on pilots and controllers being well trained in standard phraseology. But this phraseology also needs to get correctly transferred into cockpit talk and work. Both are covered extensively by procedures (ICAO Annex 6 and ICAO PANS-ATM), some of which are probably rendered useless or less robust with controller-pilot datalink communication. Of course, one could think that controller-pilot datalink simply replaces voice communication with written messages, which are then transmuted similarly into cockpit talk and work, but this is probably an oversimplification. It is more likely that the cognitive architecture and communication flow patterns through the cockpit (and to/from the cockpit) will change with the introduction of controller-pilot datalink (cf Hutchins, 1995). How the patterns will change and the implications of these changes are only partly studied. Previous studies of datalink communication in flight deck operations have shown that air-ground communication, intra-cockpit communication, human-machine interactions, as well as the “party-line” effect (hearing multiple aircraft in the area on the frequency) are likely to be affected by a shift from voice to datalink communication (Navarro and Sikorsky, 1999). In a study of flight crews in simulated controller-pilot datalink environment Harvey et al (2002) claimed that intra-crew communication increased for controller-pilot datalink flight crews compared to traditional "radio crews". But are these changes the only ones to be anticipated? The cited studies are confined mostly to simulated environments. Although they shed some light on how controller-pilot datalink affects communication between pilot and controller, we still know very little about its qualitative impact on intra-cockpit work. Voices of concern from the operational community (Garret, 2004) also show that introduction is viewed with mixed feelings. The study reported here aimed to trace the qualitative effects of controller-pilot datalink on talk and work inside the flight deck as well as issues relating to the chosen interface for the technology. By studying the effects we hope to anticipate some of the effects of this technology change so as to better adapt interfaces, procedures and expectations for controller-pilot datalink.

Method

Since December 2003, suitably equipped aircraft in the area of responsibility of Maastricht Upper Area Control, comprising of Hannover, Amsterdam and Brussels Upper Flight Information Region (UIR) have exchanged controller-pilot datalink messages with Maastricht Upper Area

Control Centre (UAC) as part of a datalink development programme called the Link 2000+ programme. We used this opportunity to study the actual use of controller-pilot datalink in the cockpit with line pilots flying normal line flights in a normal operational environment. To trace changes in cockpit work we decided to rely on cockpit observations using ethno methodological techniques, which previously have shown their usefulness in laying out cockpit communication patterns and cognitive architectures (Hutchins, 1995).

During a period of 11 months we observed 10 line flights in the cockpit jump seat, staying in the cockpit for the duration of the flight. The studied flights were opportunistically chosen from flights routed through the Maastricht control area. One half of the flight time was flown outside the controller-pilot datalink area of Maastricht control and served as a voice communication contrast condition. The pilots of the observed flights were line pilots flying the latest version of the B737 for a major air carrier in Northern Europe. The aircraft's radio and control and display software were modified from the standard B737 to support controller-pilot datalink. The pilot's experience on the B737 varied between 500 and 2000 hours. Experience from controller-pilot datalink varied from zero flights to 20 flights. The pilots had received written information about the functionality of the controller-pilot datalink system before using controller-pilot datalink, but no hands-on training before their first flight using the system. The pilots' previous controller-pilot datalink experience before the observed flight increased during the study from only one previous controller-pilot datalink flight for flight 1 and 2 up to an experience of 20 previous controller-pilot datalink flights for flight 10. There are no reasons why the pilots in the study would not be representative for the pilots of the studied airline.

The controller-pilot datalink interface in the cockpit was the Multifunction Control and Display Unit (MCDU) and the common display system (CDS) showing an "ATC" alert message together with an aural chime to indicate an incoming controller-pilot datalink message (figure 1). The cockpit chime system was inhibited at speeds higher than 40 knots until above 10000 ft pressure altitude.

Insert Figure 1about here

To read the controller-pilot datalink messages the communicating pilot then selected a controller-pilot datalink menu to show the message in the display (figure 2). The pilot responded using the same display from one of possible reply alternatives.

Insert Figure 2about here

The datalink message set had initially been restricted to a small subset of all possible controller-pilot datalink communication by the Link 2000+ project management. Flights 1 to 4 used this smaller message set. During the course of the study this message set was increased to also include altitude clearances both with and without conditional restrictions; (CLIMB FLIGHTLEVEL XXX,

DESCEND FL XXX WITH MORE THAN YYYY FPM (feet per minute)) and heading (HDG) instructions. Flights 5 to 10 used the larger message set.

Insert table 1 about here

One of the authors acted as observer. He was a domain expert (with no active role in the Link 2000+ programme) holding a valid B737 type certificate. Before observing the flights the observer contacted the pilots to receive their consent to participate in the study. Consent from the pilots was given on the basis that individual data would be kept confidential.

Observations from each flight were noted by pen and paper by the observer using the phase of flight as the frame of reference for the observations. The observation notes were structured in three columns to separate between Pilot Flying (PF), Pilot Not Flying (PNF) and Air traffic controller (ATC) actions and focused on how pilots shared and distributed messages from the controller, being either carried by voice or controller-pilot datalink. Both verbal and non-verbal communication was noted. Pilot voice communications with the controller, internal communication in the cockpit, actions with the controller-pilot datalink system and actions with the flight guidance system were noted. Events such as external agents directly influencing the operations such as ATC and ground personnel talking to the flightcrew were also noted. During quiet moments of the flight the observer interviewed the pilot's about their thoughts and experiences on controller-pilot datalink. Periods where the observer rated any of the pilot's task-load of being high were marked in the notes. High taskload was defined as periods where the observer estimated that the reserve cognitive capacity of the flightcrew was limited to the extent that additional tasks could not be given enough attention by the flight crew. After the flight the observer asked the flight crew clarifying questions, where he used his notes as a base for further inquiries of the pilots.

The first step in successive steps of processing the collected data was to transcribe the hand-written notes of the observer into a written document. Continuously as the observation flights were performed, the observer transcribed raw data from his notes on a one-to-one basis to a written document, using the hand notes. Every flight was noted on a separate document using domain specific raw data terminology.

The transcripts were then used for further analysis where the raw data was analyzed with respect to communication strategies and interface issues described in domain specific language. Ethno methodology is about a constant, co-developing interplay between data, concepts and theory, so after the first four flights we conducted a preliminary analysis, with our focus on the sort of cockpit work that aims to have both pilots equally informed about the progress of the flight. We focused on how intra-cockpit communication and controller-pilot datalink was coordinated with special emphasis was on high task-load situations. That meant searching for and identifying differences between the segments of the same flight using controller-pilot datalink and the segments of the same flight using voice communication. The early interpretation of how the pilots performed their work was compared to the literature. This guided the next empirical encounter when we decided to extend the study over time to collect more data in order to see whether we could detect any changes to the cockpit coordination activities coinciding in time with the expansion of the controller-pilot datalink message set. Our initial analysis also triggered interview questions about perceived authority and priority of controller-pilot datalink so this was pursued in interviews during the six last observed flights.

Results

Aircrews were very willing to participate and tell of their experiences with controller-pilot datalink. The findings from the observations together with the respondents' views are discussed under respective subheadings below.

Use of the controller-pilot datalink message set

Of all the possible messages in the increased message set, only messages containing altitude clearances were used. Heading instructions over controller-pilot datalink were never used by ATC. In a number of cases the controller issued a heading instruction over radio to an aircraft that he/she had given other clearances to via datalink. It seems that heading instructions carry a sense of urgency that make it unsuitable for controller-pilot datalink. Multi-element, or concatenated messages that contain more than one message element in one message such as CL FL310 AND FLY HEADING 290 were not used during by any controller in the study although they were available to the ATC (Air Traffic Control) controllers.

Controller-pilot datalink changes pilot cockpit work

Normal pilot task sharing is traditionally with a pilot flying (PF) handling the controls and a pilot not flying (PNF) in a monitoring/supporting role that also handles external communication (ICAO Annex 6). Depending on airline tradition, the PF and PNF roles are more or less clearly spelled out in their operating instructions. Radio communication however, is traditionally a PNF responsibility. This task distribution forces the pilots to coordinate their activities with an external agent that is physically not present. Through years of development the aviation community has come to grips with voice communication and to an operational understanding of how voice communication should be integrated with other cockpit tasks. To understand the mechanisms at play here Hutchins and Klausen (1996) used the terminology of "trajectories of information" to describe information flow in such settings. This notion was further developed by Nevile (2004) who wrote about how pilots integrated talk within and beyond the cockpit; "what pilot hear, and understand of what they hear, is (also) thoroughly social and emerges through processes of talk-in-interaction.

Industry practice requires the communicating pilot, usually PNF, to read back air traffic control clearances, altimeter settings and instructions. Such a requirement was also the case for the airline in this study. The other pilot then repeats the significant parts of the messages to ensure that both pilots have understood the clearance (and understood it the same way). This investment in redundancy supposedly ensures accurate controller-pilot communication. Our work, however, showed that it might have other roles as well. Especially those related to transforming air traffic clearances into flight guidance automation settings.

Insert figure 3 about here

Industry practice also requires the pilot flying to state his actions and intentions as the flight proceeds by calling out entries in the flight guidance system. If we see communications as patterns of information flow (c.f. Hutchins, 2000) the flightdeck communication loops for voice communication procedures can be graphically described in as in figure 3. With voice communication, both pilots can potentially hear the air traffic clearance through speakers or headphones. The PNF then reads back the clearance to the controller and the PF repeats its significant parts. If the message implies a change to the flight guidance system (autopilot and/or flight management system) the PF typically inserts the new target value and PNF confirms this value by calling out "checked". Figure 3 shows these multiple information loops. The first loop is the one between controller and aircraft. Both pilots participate in this loop. The second loop is what we call the intent loop. The aim of this loop is to keep both pilots aware of the PF's intentions as the flight proceeds. We called the third loop the action loop. With the action loop both PF and PNF verify that PF has entered the correct value in the flight guidance system. Both pilots are involved in all three loops in this system. However, PNF is the connecting point for all three loops; securing that the action of the aircraft complies with the message communicated by the controller. The pilots in the study adhered to this procedure for the voice communication part of the trip to the extent possible. In times where one of the pilots was in doubt of correct altitude, the PNF requested a confirmation of the value from the air traffic controller. An example from flight number seven, descending into Amsterdam, shows how the PF requested the PNF to verify the correct altitude:

ATC: “Flight XXX descend flightlevel 250 and fly heading 220";
PNF to ATC: “Descend flightlevel 250 and fly heading 220, Flight XXX”;
PF intra-cockpit: “Just confirm flightlevel 250”;
PNF to ATC: “Confirm flightlevel 250”;
ATC: “Confirming flightlevel 250”
PF then selected level change mode on the cockpit’s mode control panel and announced in-cockpit: “Level change".

During the controller-pilot datalink trials the pilots had received no additional instructions on how to change or augment the normal voice communication procedures pertaining flightdeck duties during controller-pilot datalink communication. Therefore we assumed that the pilots would let PNF handle controller-pilot datalink in line with the formal voice communication procedures. This was also the observation in the majority of the studied flights. However, sometimes conflicting with the PNF-communication rule we observed a tendency for the pilot with most experience with controller-pilot datalink to manage the datalink communication regardless of PF/PNF position. This tendency disappeared with increasing controller-pilot datalink experience of both pilots.

During controller-pilot datalink communication the observed intra-cockpit patterns were different than with voice communications. See figure 4. The main difference was that the substance of ATC clearances received via CPDCL was not audible to both PNF and PF simultaneously. While using controller-pilot datalink, the PF could not participate in the communication loop unless the message was either verbalized by the PNF or read from the cockpit interface by the PF.

Insert Figure 4 about here

During eight of the ten observed flights the communicating pilot verbalized the message before replying to it via datalink, meaning that the pilots worked actively to re-create the intention loop for both pilots (previously given by the nature of voice communication). Here is one example from flight nine:

Chime and a visual ATC alert message notify an uplink controller-pilot datalink message. PNF: “ATC! Descend flightlevel 250”

PF: “Yes” (and sets mode control panel to flightlevel 250)

PNF: replies WILCO via controller-pilot datalink to ATC.

With more controller-pilot datalink experience, pilots increasingly verbalized the content of the controller-pilot datalink messages. During the later flights of the study we noted that the controller-pilot datalink -communicating pilot (almost exclusively the PNF after flight five) almost always verbalized the content of the controller-pilot datalink message before answering. This intra-cockpit communication also included a response of some kind from PF before the PNF sent a datalink reply to the message. PF responses varied from a nod, to a verbal expression of acceptance. In some instances PNF waited for the PF to insert the new cleared altitude in the flight guidance system before replying to the message. This intra-cockpit verbalizing of the controller-pilot datalink message seemed to be a strategy developed naturally by the pilots to mitigate the risk that the communication loop and the other cockpit loops would be separated. During flight six the commander talked to the cabin crew over the interphone system while a controller-pilot datalink "DIRECT TO" clearance arrived. The copilot, despite being the PF, immediately replied "WILCO" (will comply) over datalink without disturbing the commander in his conversation with the cabin crew. When the commander was ready with cabin crew conversation he immediately verified that the copilot had already sent a WILCO reply to the controller. This shows how the flight crew actively invests time in coordination to remain in the loop. It also may point to a possible weak link in the controller-pilot datalink system; the communication loop is stronger but may be separated from the other intra-cockpit intent and execution loops.

Complementary to the observation that during eight out of then flights the communicating pilot verbalized the incoming datalink message was the observation that two out of ten flights did not. It was observed that in some flightcrews the PNF responded quickly with a "WILCO" without sharing the information with the other pilot. This behaviour was mostly observed during high task load situations for example during flight 6 as referred to above. The risk involved in the weakening of the intra-cockpit communication loop is obvious. Taking out human involvement strengthens the external communication loop. However, pilots must now drive the intention and the execution loops by themselves without any cues from other actors (as in voice communication). With controller-pilot datalink the pilots can fail to execute a clearance accepted by datalink if the PNF-PF communication gets disturbed. Failures of omission are by definition hard to detect. The controller can detect the failure of an aircraft to execute a manoeuvre, but cannot detect a failure of changing to a new frequency. In a total voice-communication free future, this failure mode will probably be addressed by a change in technology (which itself may produce new side effects).

For legal reasons at the time of our trials, pilots had to verify any controller-pilot datalink air traffic control clearance not only by using a controller-pilot datalink downlink reply, but also by voice, for example saying "Flight 1581 datalink climb flight level 360". The voice communication from pilots was done after controller-pilot datalink downlink reply in the majority of cases. In two cases this redundant voice procedure interfered with the internal cockpit coordination work, leading to uncertainty of who of the two pilots was doing what. In all cases the pilots replied without hesitation via controller-pilot datalink. The required doubling of reply modality is a typical example of how an intended investment in safety can lead to confusion and breakdown of coordination, thereby being counterproductive to its intentions.

Task shedding

Communication is not the only cockpit task. Communication has to be managed and coordinated with other cockpit work related to flying the aircraft through the air and navigating along the prescribed route. To coordinate all flightdeck tasks pilots are taught to "fly, navigate and communicate – in that order". In partial conflict with this basic rule all air traffic control voice transmissions were replied to immediately, even at the cost of internal flightdeck tasks. During flight 5, the PNF communicated with the controller instead of setting up approach waypoints to Amsterdam as requested by PF. It seems that this sense of urgency to reply to the controller carried over from voice air traffic control communications to controller-pilot datalink. The flightcrew of flight 8 when interviewed stated that controller-pilot datalink allowed them to respond to messages when the workload was low. But (contrary to this statement) the same flightcrew let handling of controller-pilot datalink interrupt other cockpit activities such as checklist reading and required callouts to confirm correct flight guidance setting—not untypical for other crews either.

Practitioners adapt the application of procedures in the face of practical demands and other sources competing for their attention. For example, air traffic controllers under high workload are known to postpone the updating of flight progress strips until they are back in a workload trough—even though legal requirements dictate they should update flight progress strips while they are giving commands (Manning, 1995). The issue is one that has been called "shedding"; the shedding of (secondary) tasks. Some researches think of shedding as a by-product of cognitive tunneling (Huey and Wickens, 1993). The prediction of what tasks will be shed is influenced by perceived priority as well as the task at hand in the existing context as we will show in the next section.

Formal and perceived controller-pilot datalink priority

Controller-pilot datalink is associated with the acceptance of a slower response time than voice communication. We identified a pattern of informal intra-cockpit prioritizing, however, as our observations progressed. For example, during flight 5 a flightcrew received a late runway change during the descent towards Amsterdam Schiphol airport that immediately increased the flight crew task load, as they had to prepare for an approach to an unexpected runway. In the midst of this high task load situation the PF took over handling an incoming controller-pilot datalink message when the PNF was busy entering data into the flight management computer.

Based on observations from the ten flights in the study we were able to construct a table how a number of discrete tasks involving communication of some kind were prioritized in order of falling priority (table 2). The table does not contain higher-order tasks like "flying the airplane". There were indications, however, that controller-pilot datalink competed successfully for attention with other tasks.

Insert table 2 about here

Table 2 suggests that communications that called for a reply from another actor, received priority. This was valid for both extra-cockpit as well as intra-cockpit communication. Voice air traffic control communication and controller-pilot datalink shared the perceived importance, although voice communication is more salient. Controller-pilot datalink received high priority in relation to other cockpit activities in our study. Within the 11 months of this study we could not determine whether this was due to the novelty of the controller-pilot datalink function or an inherent part of communication, independent of technological mode.

Interface design issues

The controller-pilot datalink shared the multiple control and display unit (MCDU) with the flight management computer system (FMC), the Aircraft Communications Addressing and Reporting System (ACARS) and the aircraft central monitoring system on the B737-NG. This meant that the pilots constantly had to prioritize from which system he needed visible information from at any given time. When flying with controller-pilotdatalink connection established, seven out of ten pilots in the study let their MCDU display the controller-pilot datalink related pages after the first controller-pilot datalink message uplink was received, rather than reselecting FMC pages. This represents a departure from the previous routine setup, and a possible confirmation of the perceived importance of air traffic control communication. Indeed, when asked why they used this display setup the pilots referred to less navigating workload and higher preparedness for new messages. An issue that has been known for ten years now with respect to flight management and how to navigate between the numerous pages of that system (FAA, 1996).

Some error messages generated by the system were not obvious to the pilots. On flight 10 the pilots sent a request for a direct route via a controller-pilot datalink message to the controller. The response from the system was an "ATC" message alert together with the message "ERROR INSUFFICIENT RESOURCES". When the communicating pilot received this message he looked for more information on a possible next page. Both pilots were now unsure whether there was a need to reiterate the request. During this event, other tasks in the cockpit such as calling out entries in the flight guidance system by PF were not attended to.

Conclusion

The trials gave insight in how pilots worked to integrate controller-pilot datalink in the overall workflow of standard cockpit work during cruise. The data assembled in this research shows that controller-pilot datalink transforms, or even interferes with, routine intra-cockpit communication during normal line operations. Pilots themselves took initiatives to verbalize datalink messages so as to re-create cues for the flightdeck intention and action loops that previously were a natural by-product of voice radio-telephony.

The blurring of traditional PF and PNF duties that was already associated with cockpit automation (Sarter and Woods, 1995 and 1997) occurs even more frequently with controller-pilot datalink, as PF and PNF sometimes perform duties in the other pilot's area of responsibility without explicitly coordinating this.

The interface design with a controller-pilot datalink sharing the interface unit with the Flight Management Computer on the studied B737 in the study makes the concept unsuitable for other than en-route communication for non time-critical messages. Connected to this issue is the phenomenon of task shedding that does occur and can to some extent be predicted according an informal task hierarchy on the flightdeck.

The introduction of controller-pilot datalink technology creates qualitative changes of work routines. A positive effect of controller-pilot datalink is that the communication loop between the aircraft and the controller is strengthened and guarded against misunderstandings, reception problems and language barriers. What is given with one hand, however, is taken away with another: controller-pilot datalink changes intra-cockpit communication loops and upsets previously followed coordination routines and procedures to verify the correct execution of air traffic controller instructions. Carriers wishing to introduce controller-pilot datalink need to carefully consider the use of cockpit procedures and pilot roles in order to ensure that previously existing communication redundancy is not eroded away. Also, additional studies of controller-pilot datalink effects on flightdeck work during other phases of flight are needed before allowing controller-pilot datalink during departure or approach phases of flight.

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Tables

Initial message set at the start of trials	
Message	**Meaning**
UNABLE	ATS cannot comply with the request
STANDBY	ATS has received the message and will respond
PROCEED DIRECT TO	Proceed direct from present position to specified position
CONTACT ((unit name) (frequency)	Contact (unit name) via voice on specified frequency
SQUAWK (code)	Select specified code (SSR code)
CHECK STUCK MICROPHONE (frequency)	Same as Message
SQUAWK IDENT	Activate the SSR "ident" function
WILCO	The message is understood and I will comply
Uplink Messages after first four (4) flights	
Message	**Meaning**
MAINTAIN (level)	Maintain indicated flight level
CLIMB TO AND MAINTAIN (level)	Climb to an maintain indicated flight level
DESCEND TO AND MAINTAIN (level)	Same as Message
TURN (direction) HEADING (degrees)	Same as Message
CONTINUE PRESENT HEADING	Same as Message
MONITOR (unitname) (frequency)	Select specified frequency and monitor
FLY HEADING (degrees)	Same as Message

Table 1. controller-pilot datalink message set during the trials

Voice air traffic control communication
controller-pilot datalink communication
Cockpit callouts requiring action from the other pilot
Approach or takeoff briefing
Cockpit callouts not requiring an action from the other pilot
Routine cockpit-cabin crew communication
Datalink communication with company (ACARS)

Table 2. Observed informal priority of a selected set of intra-cockpit activities aimed at coordinating the agents. Activities listed in order of falling priority.

Figure captions

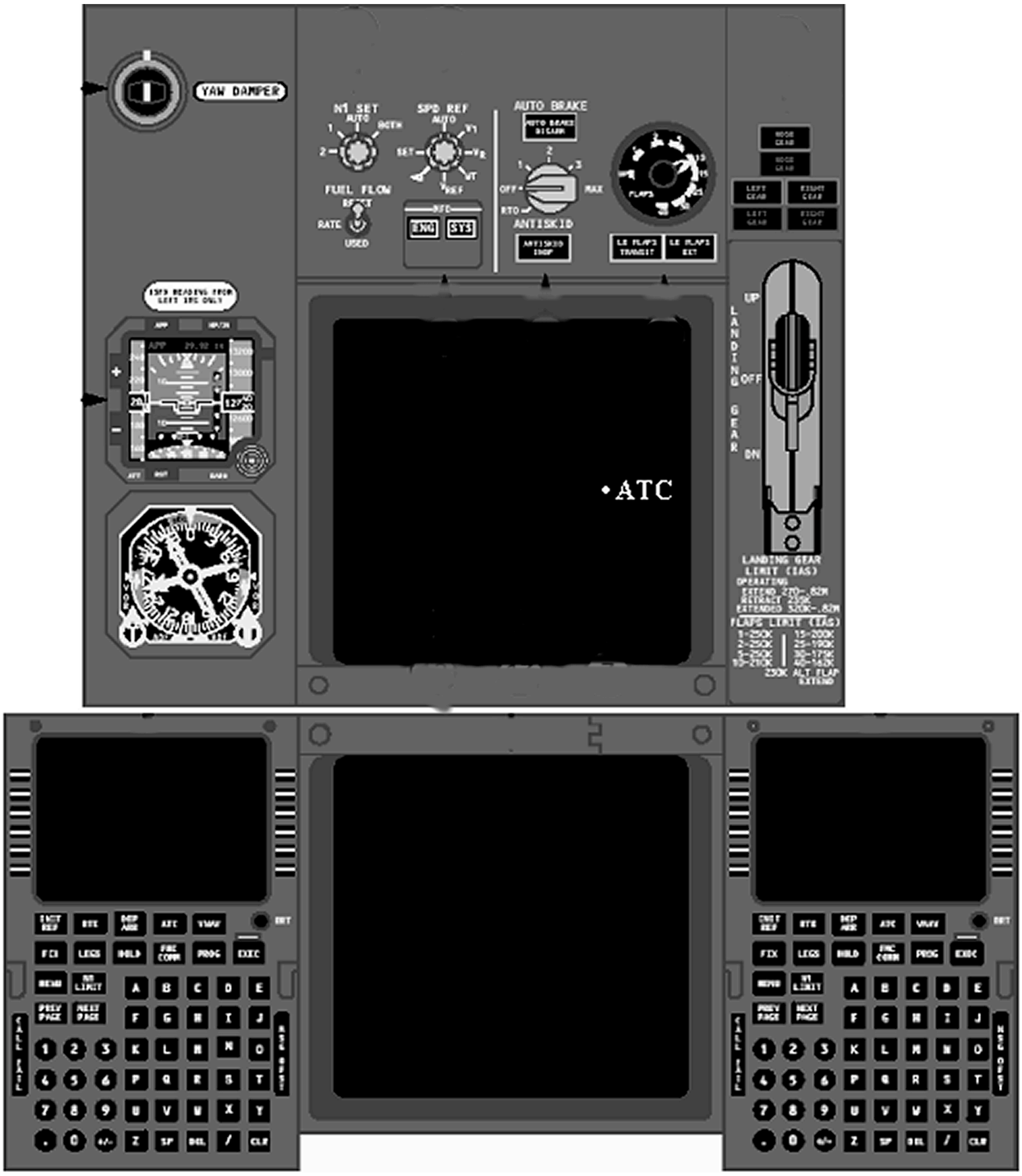
Figure 1. Center forward panel and Forward Aisle stand of a B737-NG aircraft with one Multiple control and display unit (MCDU) on each side of the lower display unit. The ATC alert on Upper Display Unit indicates an incoming controller-pilot datalink message. Picture adapted from 737-683/783/883 Operations Manual with permission from The Boeing Company.

Figure 2. Close up picture of the Multiple control and display unit (MCDU) showing an incoming controller-pilot datalink message instructing the pilots to contact Jacksonville center. The possible responses WILCO and UNABLE as well as a possibility for the pilot to print out the message appear below the dotted line. With permission from Rockwell-Collins and The Boeing Company.

Figure 3. Graphical representation of information loops in play during voice radiotelephony communication

Figure 4. Graphical representation of information loops in play during controller-pilot datalink communication

Figures


YAW DAMPER
N1 SET
AUTO
BOTH
SPD REF
AUTO
FUEL FLOW
RESET
RATE
USED
ENG
SYS
AUTO BRAKE
OFF
RTO
MAX
ANTISKID
FLAPS
UP
OFF
DN
LANDING GEAR
ATC

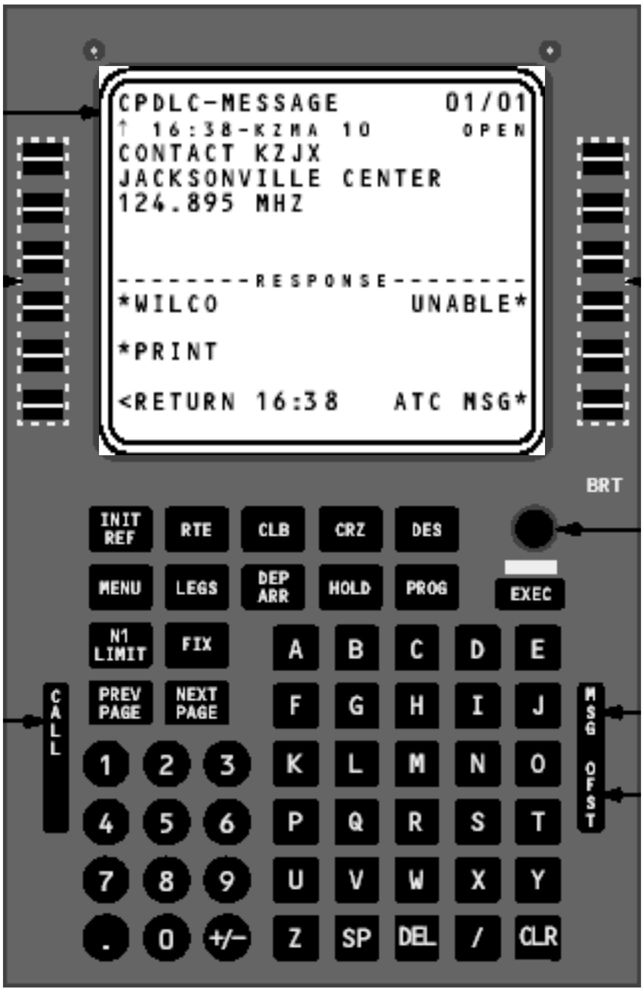

CPDLC-MESSAGE 01/01
↑ 16:38-KZMA 10 OPEN
CONTACT KZJX
JACKSONVILLE CENTER
124.895 MHZ
--------RESPONSE--------
WILCO UNABLE
*PRINT
<RETURN 16:38 ATC MSG*
BRT
INIT REF
RTE
CLB
CRZ
DES
MENU
LEGS
DEP ARR
HOLD
PROG
EXEC
N1 LIMIT
FIX
PREV PAGE
NEXT PAGE
CALL
MSG
OFST
A B C D E
F G H I J
K L M N O
P Q R S T
U V W X Y
Z SP DEL / CLR
1 2 3
4 5 6
7 8 9
. 0 +/-

Figure 2

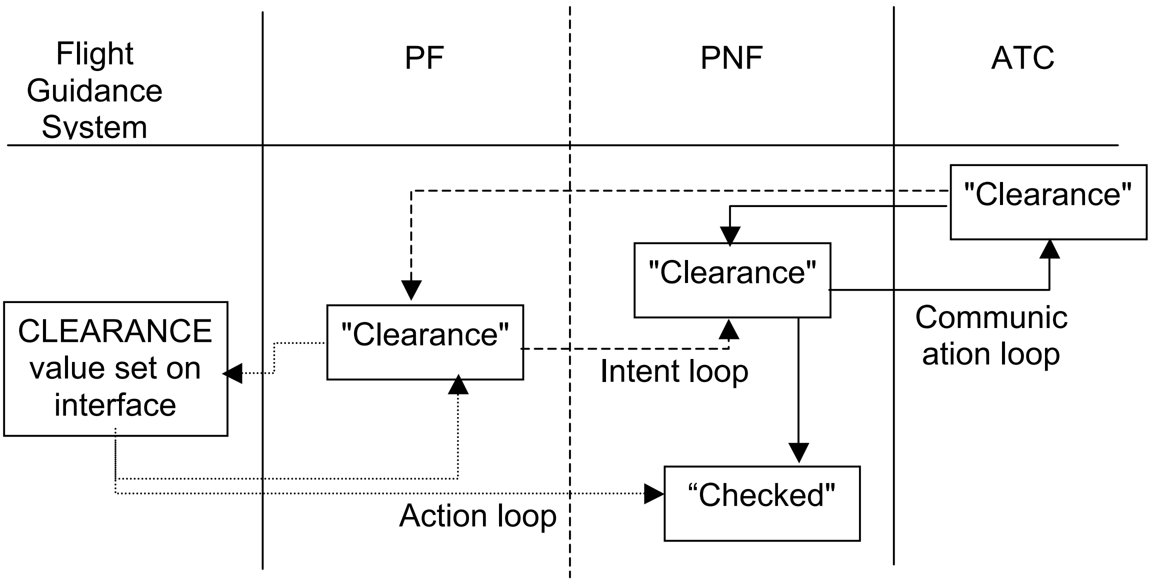

Flight Guidance System
PF
PNF
ATC
"Clearance"
"Clearance"
"Clearance"
CLEARANCE value set on interface
Communic ation loop
Intent loop
"Checked"
Action loop

Figure 3.

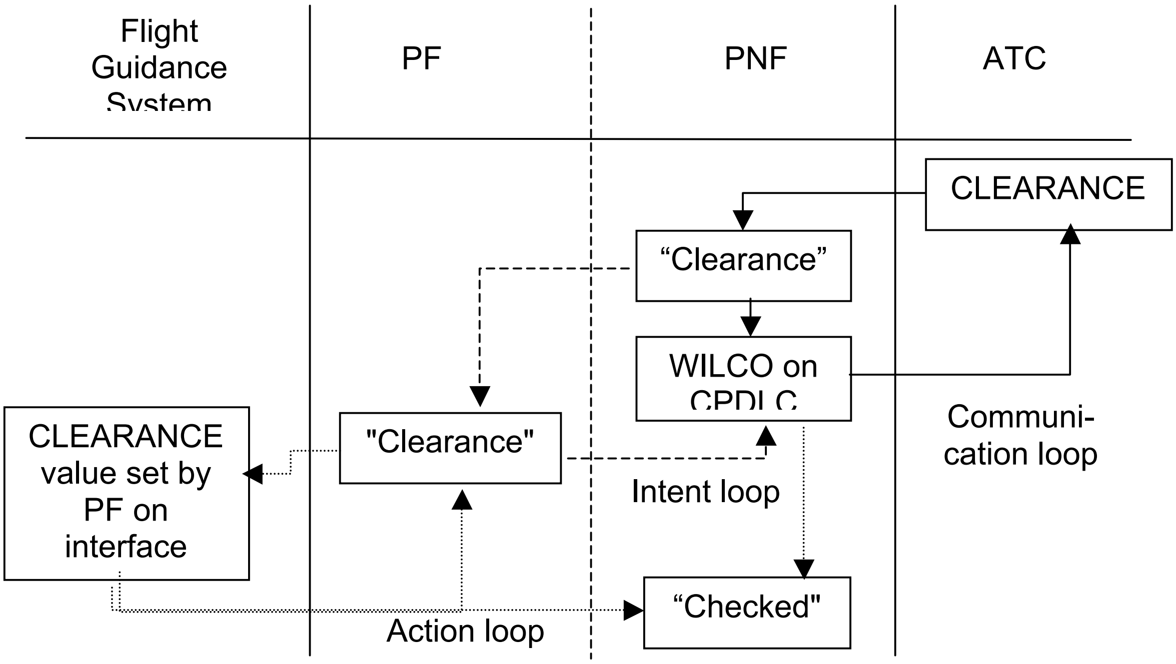

Flight
Guidance
System
PF
PNF
ATC
CLEARANCE
“Clearance”
WILCO on
CPDLC
Communi-
cation loop
CLEARANCE
value set by
PF on
interface
"Clearance"
Intent loop
“Checked"
Action loop

Figure 4.