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16. ABSTRACT

Honeywell explored the limitations and capabilities of the Controller/Pilot Data Link Communications (CPDLC) interface with aircraft navigation and guidance systems. This report contains sections describing a literature review, an engineering analysis methods and results, and recommendations. The literature review covers an overview of differences in human-machine interface (HMI) among the platform types, LOADABLE ATC clearances, equipage levels among new generation and legacy Boeings, data entry checking features, and a section on new technology that may impact CPDLC in the future. The engineering analysis sections describe the analysis methodology and the results of observed capabilities and limitations for each Boeing platform based on the simulator analysis. The recommendations section includes recommendations for CPDLC crew procedures, compliance with CPDLC procedures, system design, and future research. Both manual and auto-loading CPDLC functions were evaluated in a real-time nominal 'flight.' A variety of air traffic control (ATC) uplink message (UM) elements were selected based on clearance auto-loading into the flight management system (FMS), message complexity and category. Message categories included concatenated, conditional and route modification, speed, altitude, and time (Required Time of Arrival (RTA)) messages. The analysis used several platforms, including first generation FMS and glass cockpit aircraft and newer generation aircraft with graphical user interface (GUI) displays and cursor controls. Aircraft used in the study included the Boeing 787, Boeing 777, Boeing 744, and the Boeing-733. An important consideration was to understand the proper task sequences in retrieving and responding to each ATC uplink message so that error-free and compatible procedures could be developed. Once an ATC uplink was sent to the on-board CPDLC system, it was necessary to understand all the crew tasks required to retrieve the message, evaluate the clearance, and configure the automation to execute the clearance. Only ATC uplink clearances were evaluated.

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Prepared for:
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Prepared by:
Honeywell
Aerospace Advanced Technology
21111 N. 19th Ave. M/S 2J35A5
Phoenix, AZ 85027

Honeywell

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RESEARCH TEAM:

TEAM MEMBER	ROLE	LOCATION	PHONE
Dave Pepitone, PhD (david.pepitone@honeywell.com)	Program Manager	Phoenix	602 436-5505
John Fugedy, Capt. (John.Fugedy@Honeywell.com)	Technical Manager	Albuquerque	505 828-6518
Emmanuel Letsu-Dake, PhD (Emmanuel.Letsu-Dake@honeywell.com	Senior Scientist, Human Factors	Minneapolis	763-954-6225

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1. Executive Summary

Under FAA Contract DTFAWA-10-A-80031, Honeywell explored the limitations and capabilities of the Controller/Pilot Data Link Communications (CPDLC) interface with aircraft navigation and guidance systems.

This report contains sections describing a literature review, an engineering analysis methods and results, and recommendations. The literature review covers an overview of differences in human-machine interface (HMI) among the platform types, LOADABLE ATC clearances, equipage levels among new generation and legacy Boeings, data entry checking features, and a section on new technology that may impact CPDLC in the future. The engineering analysis sections describe the analysis methodology and the results of observed capabilities and limitations for each Boeing platform based on the simulator analysis. The recommendations section includes recommendations for CPDLC crew procedures, compliance with CPDLC procedures, system design, and future research.

For the engineering analysis, we analyzed the B-787, B-777, B-744, and B-733 CPDLC FMS interfaces under real time CPDLC scenarios with the goal of developing recommendations for CPDLC operating procedures. System and crew observations were used to develop CPDLC crew procedures, recommendations for system design, recommendations for CPDLC compliance, and recommendations for future research. The results of this work will be validated in a full mission Line Oriented Flight Training (LOFT) scenario in Phase II of this program, to begin in September 2011.

Both manual and auto-loading CPDLC functions were evaluated in a real-time nominal 'flight.' A variety of air traffic control (ATC) uplink message (UM) elements were selected based on clearance auto-loading into the flight management system (FMS), message complexity and category. Messages included single variable messages (e.g. ALTITUDE) and multiple variable messages (e.g. ALTITUDE, SPEED, and POSITION). Message categories included concatenated, conditional and route modification, speed, altitude, and time (Required Time of Arrival (RTA)) messages.

The analysis used several platforms, including first generation FMS and glass cockpit aircraft and newer generation aircraft with graphical user interface (GUI) displays and cursor controls. Aircraft used in the study included the Boeing 787, Boeing 777, Boeing 744, and the Boeing-733. The Boeing 787 and Boeing 777 can load uplink messages directly into the FMS. The Boeing 744 and the Boeing 733 were used to evaluate manual loading behavior using communications management unit (CMU) equipage (similar to the Mark II Honeywell CMU). The CMU uses the multipurpose control and display unit (MCDU) interface to present CPDLC menu pages. The CMU shares the MCDU with other aircraft systems such as the FMS. The crew retrieves the ATC Uplink message from the CPDLC new message display page, and then manually configures the navigation (FMS) and flight guidance systems (mode control panel (MCP)) to execute the clearance.

Data collection in the simulator analyses included:

- UM type and number
- The number of system steps the pilot performed to execute, reject or cancel the clearance
- Flight deck data comm system behavior as it was relevant to CPDLC clearances
- Performance and behavior of the FMS and flight guidance systems in responding to CPDLC message elements
- System 'gotchas'
- Limitations and capabilities of each data comm system as it interfaced to the FMS

A common scenario with a set of common uplink messages was used on all Boeing platforms so that an 'apples to apples' comparison of each system's capabilities and limitations could be accomplished.

Observing and analyzing the CPDLC interface with the FMS was not sufficient to design crew procedures. To create end-to-end CPDLC crew procedures, we needed to observe the operation and crew interface of the navigation, guidance, and control systems as well as intra-crew communications. This process included not only message handling (message retrieval and response) but how the pilots evaluated and complied with the clearance using the flight deck automation.

The design of the CPDLC crew procedures was based on observed flight deck data and previously published work (for example, [23-24] and [73-74]). Their work provided the theoretical foundation for procedure design. The design goal was to build simple and efficient CPDLC procedures to mitigate potential sources of error and enhance timely clearance compliance. Another CPDLC procedure design goal was to make the procedure functional with any clearance UM type and with any flight deck CPDLC-FMS interface.

Some significant findings of the analysis were:

- Climb and descent RTAs with current FMS productions are not feasible. Prototype FMS systems for descent/climb RTAs are in-work, but certification is not expected until 2014 or beyond. Honeywell's currently certified RTA systems can adjust only cruise speed; they cannot meet an RTA in climb and have limited ability to meet an RTA in the descent phase (no ability to react to uncertainties in the descent phase). However, there are several RTA prototypes that can meet an RTA in climb or descent phase — and seem to be able to do so consistently. Although auto-throttle is not required, it would greatly reduce flight technical error and crew workload. Otherwise, the pilot has the burden of monitoring the speed bug.
- The B-787 provides dedicated glass to data comm and larger glass message areas within the pilot's primary field of view. Large clearances (e.g. extended route clearances) can be displayed within a single window pre-empting the necessity of having to scroll through two or more pages.
- The B-787 also provides system advantages in providing a side-link visual alert to advise the pilot of a conditional clearance when the aircraft is near the conditions (e.g. position) in which the conditional is expected to be executed.
- System acceptance of ATC uplink clearances is mixed across data comm systems. There are some gaps between the B-787 and B-777 in terms of what messages the FMS can recognize. The Mark II CMU interface is different yet again in terms of messages it can accept (see results section). This situation presents a mixed equipage problem, with some aircraft being able to accept some ATC clearances while others cannot.
- Phase of flight demands present unique issues with CPDLC. This report breaks the phase of flight into 'critical' segments beginning with the gate, ramp, taxi to runway, position and hold, takeoff roll, initial climb and enroute climb, and cruise. On descent, terminal area flight, monitored approaches, and missed approaches were considered. Embedded within each segment of each phase of flight, descriptions of crew flight and system tasks give a context for CPDLC procedures. It was evident from such a breakout that a great deal of coordination, delegation, and positive transfer of control are needed to enable safe operation. CPDLC puts additional visual monitoring demands on the crew, which can be distracting from concurrent visual demands (e.g. ramp taxi, crossing intersections, monitored approach in CAT II conditions, intermediate altitude level offs, etc.).

Although not in scope for this project, it will be important to consider critical phase-of-flight inhibits for CPDLC. Consideration should be given to inhibiting CPDLC (alerting) during the takeoff roll and to some XX.X NDA altitude during the initial climb (much as we do with the Engine Indication and Crew Alerting System (EICAS) and Master/Caution alerting).

- Although the frequency for using Standby is yet to be determined, putting the STANDBY control on the glare shield is not a common design standard (typical glare-shield configurations have ACCEPT, REJECT, and CANCEL buttons).
- Voice should be used instead of CPDLC during ramp operations. Aircraft-to-aircraft or aircraft and vehicle collisions on the ramp are still a large ground safety issue. The latest data [1] indicates that ramp area collisions cost the industry upwards of 3 billion dollars a year (as of 2005). The use of voice versus CPDLC was also evaluated using a critical phase of flight analysis with embedded critical events (e.g. taxiing aircraft across intersections while receiving an ATC instruction). Use of CPDLC during the taxi phase will be highly dependent upon the clearance type (simple versus complex), the cockpit technology (e.g. moving airport maps

with taxi route depictions or HUDs (head-up displays) with taxi route descriptions) and the external conditions at the time. For instance, if the crew is approaching a taxiway intersection or a runway incursion ‘hotspot,’ it may require the ‘heads up’ vigilance of both crew members. Stopping or pulling out of the lineup to respond to a CPDLC message will negatively affect airline operations and taxi system throughput.

1.1. Project Scope and Limitations

CPDLC procedures were developed in the context of a simulated ‘typical’ flight using a selected set of uplink messages (UMs). Raw data was collected by observing the CPDLC system and pilot response across a mix of Boeing platforms using Honeywell certified data comm systems.

An important consideration was to understand the proper task sequences in retrieving and responding to each ATC uplink message so that error-free and compatible procedures could be developed. Once an ATC uplink was sent to the on-board CPDLC system, it was necessary to understand all the crew tasks required to retrieve the message, evaluate the clearance, and configure the automation to execute the clearance. Only ATC uplink clearances were evaluated.

The system and crew task observations included:

- System management and alerting
- Steps necessary to retrieve the message
- How the crew built a common, shared understanding of the clearance or message
- The process by which the crew forecasted or evaluated whether they could successfully comply with the clearance (route mod, speed, altitude, time)
- FMS loading
- How the flight deck automation was set up to comply with the clearance
- The pilot techniques for accomplishing the flight deck set-up (e.g. use of VNAV, LNAV, or mode control modes)
- Use of crew crosschecks to verify the automation set-up
- Verification that the aircraft performance, guidance, and navigation was correct
- Verification that the aircraft was performing as intended
- Returning the CPDLC system to its default set-up (in preparation for the next ATC uplink).

The purpose of developing general system performance requirements, operating limitations, and standard operating procedures is to provide guidance for developing integrated versus non-integrated FMS-CPDLC systems. Developing operating limitations and general system requirements and identifying system restraints and benefits provides a knowledge base for the development of future designs and standard operating procedures (SOP).

1.1.1. Contract Deliverables

The final report includes an analytic summary of the literature as it pertains to CPDLC procedure design and the results of operational interviews and heuristic evaluations. We offer conclusions and recommendations regarding standard operating procedures and limitations with both integrated and non-integrated CPDLC flight deck implementations. The results and assumptions found in this study will be validated in a full mission LOFT scenario in Phase II to begin in September 2011.

1.1.2. Project Limitations

The authors imposed a constraint on the project to study data comm systems that were being certified and/or that have been in operational service. This criterion ensures a degree of fidelity yielding greater confidence in system behavior and operation. Per contract, it was necessary to evaluate both integrated data comm systems (B-787 and B-777) and non-integrated legacy systems (B-744 and B-733). This mix of equipage allowed the observation of different data comm HMI interfaces. The Boeing 787, 777, and 744 were equipped with Honeywell FMS systems and the Boeing 733 was equipped with a Smiths unit. In all cases, the data comm systems were Honeywell supplied.

Study conclusions were based on the task analysis of 25 ATC message uplink elements. A mix of simple and complex messages were selected to include 'autoload messages,' some concatenated messages, altitude, speed, route, and RTA messages. Each UM was observed with each Boeing model type in the context of a common flight scenario. System and pilot behavior were observed and recorded for each UM. The task analysis included how the message alerting worked, message retrieval, message loading into the FMS, and how the crew handled various CPDLC procedures such as loading, auto-loading, rejecting, and the use of STANDBY.

Uplink messages (UMs) are, for the most, part clearances for the flight crew. The same UM is handled differently depending on the CPDLC and FMS equipment capabilities of the receiving aircraft. Each system and flight deck data comm HMI had its own quirks, behaviors, and system 'gotchas.' The limitations and capabilities of each system were observed and recorded.

1.2. Terminology

Definitions of important concepts discussed in this report are contained in Appendix A. Acronyms are usually defined when used for the first time, and a complete list is contained in Appendix B.

2. Literature Review

2.1. Objectives

The introduction of Controller-Pilot Data Link Communications (CPDLC) into the National Airspace System (NAS) will offer a number of benefits to the users [115]. The CPDLC project in Miami between 2002 and 2003 represented a significant field evaluation of CPDLC in the US. The benefits identified included a reduction in voice frequency congestion. This benefit alone is driving Europe to adopt CPDLC more quickly than the US. Other benefits include the transfer of communications and aeronautical information sharing such as altimeter settings [12]. A recent study indicated the importance of developing procedures not only for mixed equipage but mixed airline procedures [56]. In a recent field study [Appendix D - ZMA and MIA TRACON Observation] observations indicated that mixed equipment combined with mixed flight procedures (e.g. STARs versus Tailored Arrivals) create an undue workload burden on the controllers. This finding highlights the need for procedures to handle mixed equipage with mixed airline profiles.

Aircraft flying in the current environment present a mix of data comm equipage levels, different pilot interfaces for handling data comm, varying levels of autoload (loadable messages) capability, and differences in FMS capabilities for accepting some SC-214 message elements. Although standardization will eventually even out the playing field, the current mix of avionics needs to be visible to those responsible for defining standards and operating procedures, as these aircraft platforms will be flying in the NAS for years to come.

The review of the relevant literature is aimed at highlighting these differences in equipage, human machine interface (HMI), and message handling while introducing new technology that is currently or will shortly be certified to fly in the oceanic environment and NAS. The literature review sections are listed below:

- Current data comm limitations and capabilities
  - Limitations and capabilities with HMI interfaces
  - Limitations and capabilities with ATC uplink message set
  - Limitations and capabilities with loadable uplink clearances
  - Limitations and capabilities with current fleet equipage
- New enabling technology developments
  - Oceanic – ITP
  - Enroute and terminal – CDTI
  - Surface operations – airport moving map displays
  - Near-to-eye displays
- Limitations and capabilities summary – implications for crew procedures
- CPDLC procedures

Figure 2-1 illustrates the project methodology of gathering current procedures, data, and analysis for procedure design.

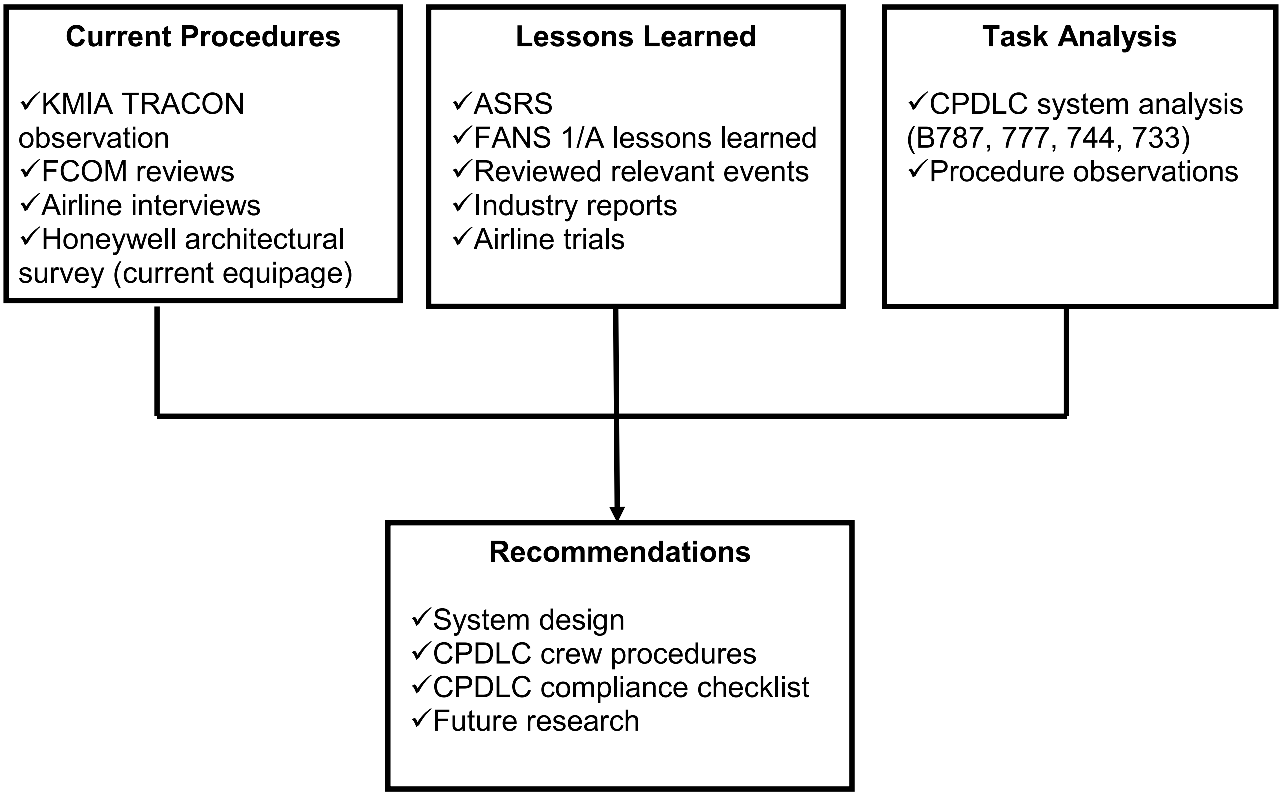

Figure 2-1. Project Methodology

2.2. HMI Differences – Capabilities and Limitations

This section highlights significant HMI differences between aircraft model types. It is not an exhaustive description of HMI differences but is intended to point out some remarkable differences in the crew interface to data comm and CPDLC. The section starts off with legacy aircraft, which are exemplary because the primary interface will be the MCDU. The MCDU has glass 'real estate' limitations as well as display limitations in the use of color, font, and other attributes that enhance the pilot interface. Later sections discuss the newer generation of aircraft, offering more optimized pilot interfaces with larger glass display areas dedicated to data comm, as well as using different means of controlling the pilot interface.

Data comm interfaces for the Boeing 787 and the Boeing 777 are very similar, and both model types will approach commonality as new 777 software loads are released. HMI differences are discussed separately, but the only significant differences on the 787 are the larger full time glass (AUX display) dedicated to CPDLC, ability of the FMS to generate help prompts, conditional clearance prompts, and dialable ATC clearances. "Dialable ATC clearances" simply means that the B-787 (and later the B-777) displays the altitude, speed, or heading in the lower part of the Mode Control Panel (MCP) window. This command value serves as a prompt so that when the pilot dials the altitude, speed, or heading to match the prompt, the prompt turns green indicating a value match. The large glass AUX ATC displays on the 787 are configured to be just adjacent (outboard) of each pilot's primary flight display. These features are discussed in detail in the following HMI sections.

2.2.1. Boeing Legacy Aircraft (744 and 733) Data Comm HMI

The MCDU is the pilot interface [10] for the CMU (communication management function). Besides other functions such as TWIP, ATIS, and AOC, the CMU mediates CPDLC.

CPDLC and data comm functions using MCDUs are the typical installation or configuration for legacy aircraft and also the standard forward fit on newer generation aircraft (e.g. B-747-8 and B-737NG). These MCDUs have a dedicated ATC function key on the alpha-numeric keypad (for the Mark II CMU MCDU the key is labeled DLK). See Figure 2-2. The CMU (communication management function) that mediates CPDLC must share the same interface with other aircraft subsystems (e.g., FMS).

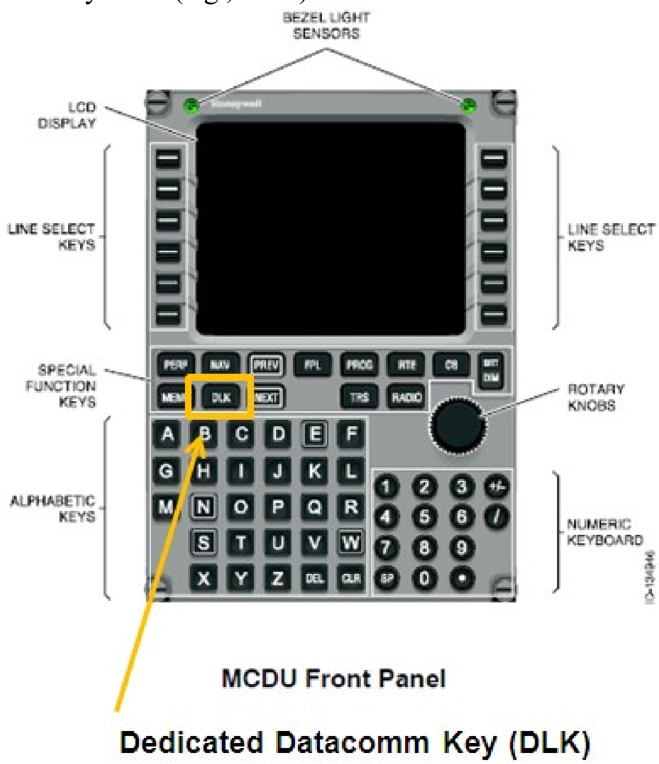

Figure 2-2. MCDU

As shown on the state diagram in Figure 2-3, when aircraft power is first applied (at the gate), the DLK function button on the alphanumeric keypad takes the user directly to the MAIN menu for the CMF function. This is the default power up condition. If there are new ATC messages, all subsequent button presses of the DLK key will display the ATC New Message page; if there are no new ATC messages, then pressing the DLK key will display the ATC message LOG.

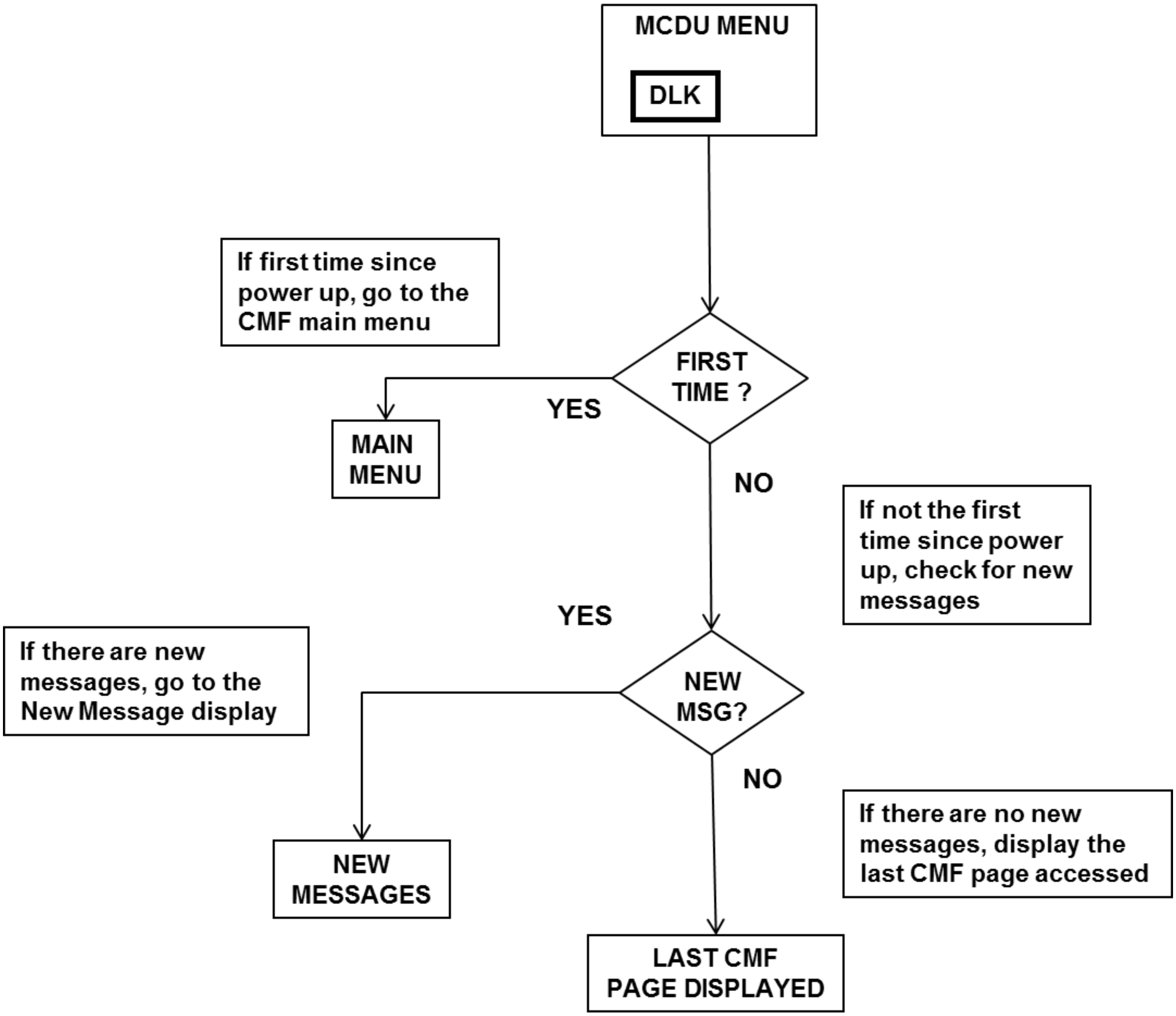

Figure 2-3. CMF Access Diagram

Figure 2-4 shows the default page shown on power up (MAIN Menu) when the DLK key is pressed. Subsequent presses of the DLK key display the ATC UPLINK MSG page *if* there is a new ATC message (Figure 2-5). If there are two or more ATC Messages, the pilot will see the ATC Message LOG after pressing the DLK key.

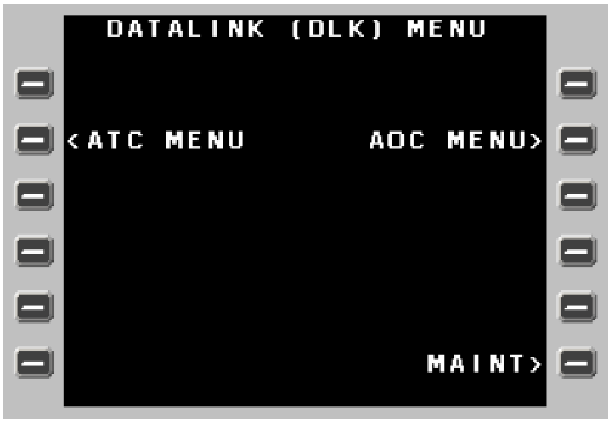

Figure 2-4. Default Power Up Page

Figure 2-5. ATC Message Page

The ATC Message LOG shown in Figure 2-6 uses color and text to indicate message status. Many OEM installations use monochrome screens that create additional clutter. The closely spaced lines and text, when not separated by space, color, font, or symbols, makes it difficult for the pilot to locate and read a text message.

The flight deck effects and crew actions for new ATC messages are summarized below:

- New ATC message is received by the aircraft
- A white advisory "• ATC" appears on the EICAS display along with a soft chime (display of the ATC advisory message is standardized across all Boeing forward fit models) See Figure 2-7.
- Crew presses the DLK function key.
- New ATC message page displays (see Figure 2-5)
- The ATC Uplink message page will show LSK prompts for WILCO (5R), UNABLE (5L) with direct access to the ATC message LOG at 6L.
- When the crew selects a response (WILCO or UNABLE), the prompt at 5R or 5L displays SENDING then SENT to indicate that the message has been received and validated by the ground computer.

The display area of an MCDU is small and constrained, displaying 24 columns by 14 rows (see Figure 2-6). Some rows are dedicated to labels, leaving very little display area for messages. Large clearances, for example [ROUTE CLEARANCE ENHANCED] may not fit on a single MCDU page, thus driving the pilot to view the clearance on two or more pages. The pilot must use the NEXT key on the alphanumeric keypad to view the entire message, and going to the NEXT page means the pilot must remember what was on the previous page. This display configuration has obvious disadvantages for a pilot who must try to enter the clearance into the FMS. Although, some clearances are loadable on the Mark 2, they are a small subset of the overall message set.
Depending on model type, some MCDUs may not have color, nor is the symbol set very large. Monochrome displays with small symbol sets are at a disadvantage in being able to highlight or separate information. In the illustration below (Figure 2-6) color is used to separate and define message type and status. Even with color, the display is cluttered. With monochrome, the LOG display places even more of a demand on the pilot.

Because of the small display areas, menu design and page navigation (Figure 2-8) is more complex than it is for the newer forward fit displays (B-787 and B-777) that have large, dedicated glass areas for data comm.

Figure 2-6. ATC Message Log

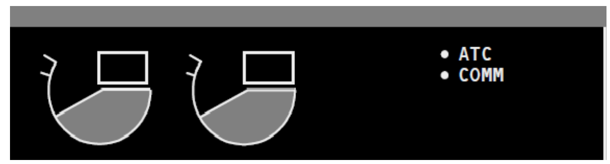

Figure 2-7. New Message EICAS Display

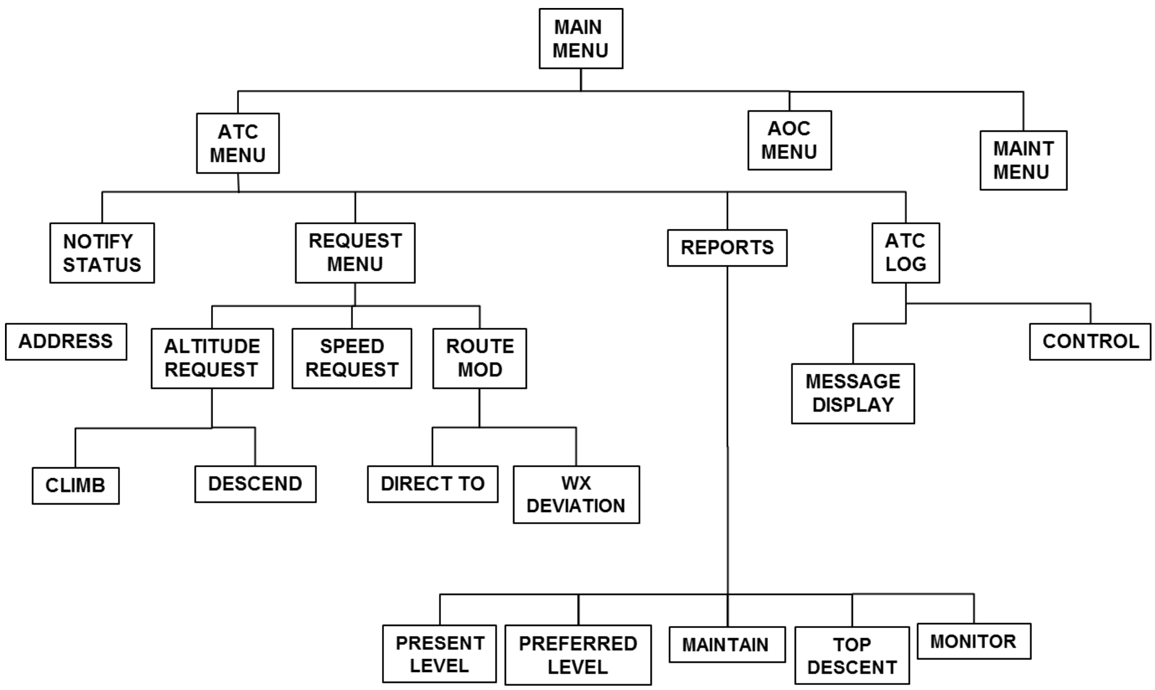

Figure 2-8. Menu Design

The installations on the legacy 744 and 737 aircraft do not have glare shield ACCEPT, CANCEL, or REJECT quick action buttons. The pilot uses the LSK keys on the MCDU bezel to send a response to ATC. The response 'handshake' display feedback is standard across Boeing types. Whether using the Mark II CMU or the installations on the newer Boeing types (777 and 787), the crew must wait for the handshake response once an acknowledgement is sent. The handshake is typically annunciated when the response type (e.g. WILCO) changes from SENDING to SENT, which acknowledges receipt of the message by the ground computer.

2.2.2. B-777 Data Comm HMI

The B-777 [8] is an MFD-based (multi-function display) system that shares commonality with the B-787. Common crew interfaces include a Comm Manager display on the MFD, an EICAS "• ATC" white advisory message that alerts the crew to a new ATC message, soft chime for new incoming ATC messages, glare-shield quick response keys, and an ATC message block in the lower left corner of the EICAS display. The crew can read and respond to the ATC uplink quickly by reading the clearance on the EICAS ATC message block and using the quick response keys to respond to ATC.

The STANDBY soft key is located within the Comm Manager display on the MFD. Like the B-787, the Comm Manager display can be moved or located on any MFD using the display control panel (DCP). Movement and selection within the Comm Manager display is accomplished via a free dual cursor located on the pedestal just adjacent to the throttle quadrant. The cursor touchpad has one-touch 'hot zones' that pop the cursor to a corner soft key on the Comm Manager display.

The B-777 is capable of inserting loadable messages directly into the FMS. Loadable messages must pass pre-load checks prior to the LOAD prompt being displayed. This minimizes pilot workload by automatically creating proper syntax and checking that the NAV database can support the clearance as well as other workload and error reduction pre-load checks. This is discussed fully in the Auto-load section of the literature review.

New message alerting is standard across Boeing types. A white advisory message ("•ATC") is displayed in the EICAS field along with a soft chime. The ATC message block is located in the lower left corner of the EICAS display (Figure 2-9).

If a larger extended clearance is received, the message block will display LARGE CLEARANCE. This prompts the crew to view the clearance on the COMM Management Unit display, which has a larger display area (see Figure 2-10). The COMM Manager display contains keys for rejecting with reasons, print, and ATC LOG. GUI icons such as radio buttons and check boxes are used to select responses. The large display areas and use of quick action keys that are located on the same page may speed pilot response.

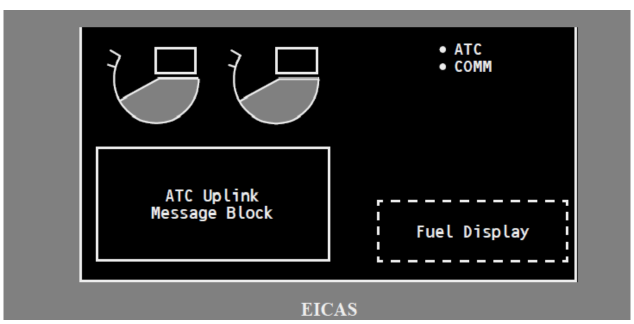

Figure 2-9. EICAS ATC Message Block

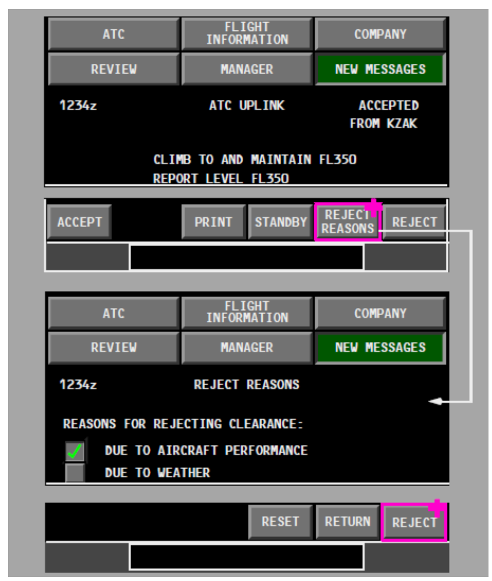

Figure 2-10. COMM Manager

Glareshield quick response keys are standard on the B-777 (Figure 2-11) and the B-787, and some legacyB-744 are also equipped with them.

Figure 2-11. Quick response keys

Crew actions for responding to an ATC Uplink message on the B-777 are detailed below:

- A soft chime and a white advisory message "•ATC" MSG appears in the EICAS message field.
- The ATC Message pops into view on the ATC message block field in the lower left corner of the EICAS display. The ATC message field on the EICAS display also contains soft keys for LOAD, CANCEL, REJECT and WILCO. Crew can select soft keys using the discrete cursor and the glareshield quick response keys. The LOAD prompt must be selected using the cursor.
- When the response is sent, the crew watches the prompt change from SENDING to SENT to verify that the ground computer has received the message.
- The crew selects the CANCEL key (soft key or glare-shield key). If there are no remaining, unacknowledged new ATC messages in the LOG, the EICAS message block and the •ATC MSG advisory on the EICAS message field go blank. The screen is then clear for the next incoming message.

2.2.3. B-787 Data Comm HMI

Figure 2-12 shows a view of all the CPDLC HMI interfaces in the B-787 cockpit. The glass MCDUs are shown just forward of the throttle quadrant. The Comm manager display can be shown on any MFD. The ATC AUX display is shown just outboard of each PFD. The ATC AUX display is a full-time, dedicated display for ATC clearances.

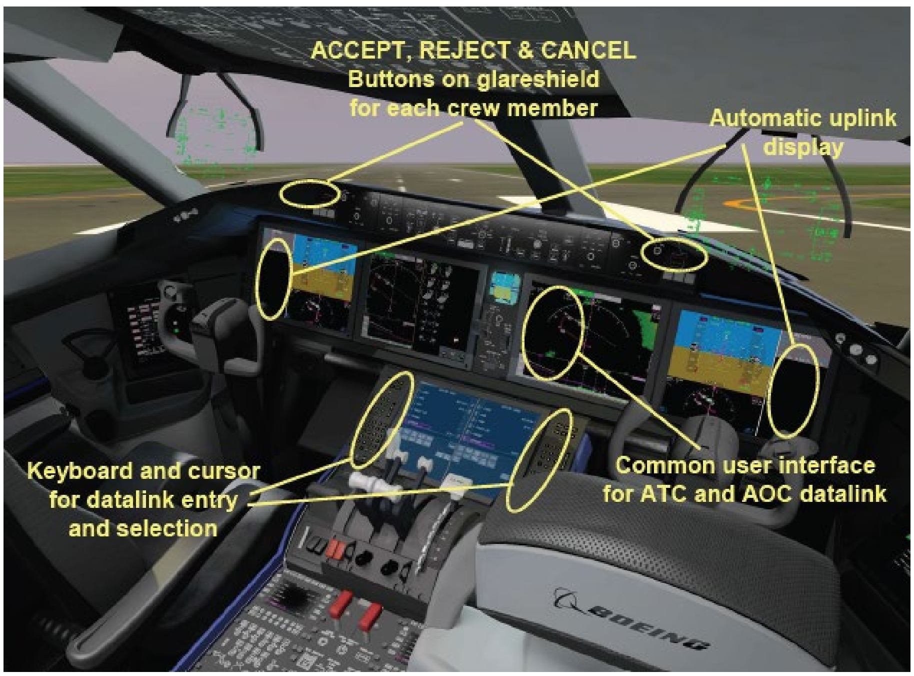

Figure 2-12. CPDLC HMI interfaces in the B-787 cockpit

Although B-787 functionality is common to the B-777, the B-787 has HMI enhancements for conditional messages [9] and FMS data entry help, which is essentially a HELP system for FMS advisory messages. The B-787 display has large dedicated glass areas (outboard of each pilot's PFD) for ATC messages. Boeing gathered lessons learned from the FANS-1 operation using the B-777. The more significant HMI lessons learned include:

- Active ATC Center (ATC message block on the glass MCDU) needed on uplink displays
- Provide MCP and TCP panel loading (loadable elements for MCP and TCP such as altitude, speed, frequency), known as DIALABLE ATC message elements
- Expand FMC loadable message set
- Conditional clearance handling and display (displayed on the glass MCDU ATC Message Block)
- Duplicate waypoint resolution
- Position reporting of compulsory waypoints

The B-787 can insert loadable messages directly into the FMS. These loadable messages must pass pre-load checks before the LOAD prompt will be displayed. The pre-load check minimizes pilot workload by automatically creating proper syntax and checking that the NAV database can support the clearance, as well as other workload and error reduction pre-load checks. This process is fully discussed in the auto-load section of the literature review.

In Figure 2-13, the ATC Clearance Message Block appears on the glass MCDU just forward of the throttle quadrant (as well as the full time AUX display outboard of the PFDs). Notice that the message block window has soft keys for loading the clearance directly into the FMS. The LOAD button can be controlled via cursor, or an enter key on the dedicated keypad located just adjacent to the glass MCDUs. The LOAD prompt will not appear unless all pre-load checks are met successfully. The dwell time for the pre-load checks is very fast and is on the order of 1-2 seconds.

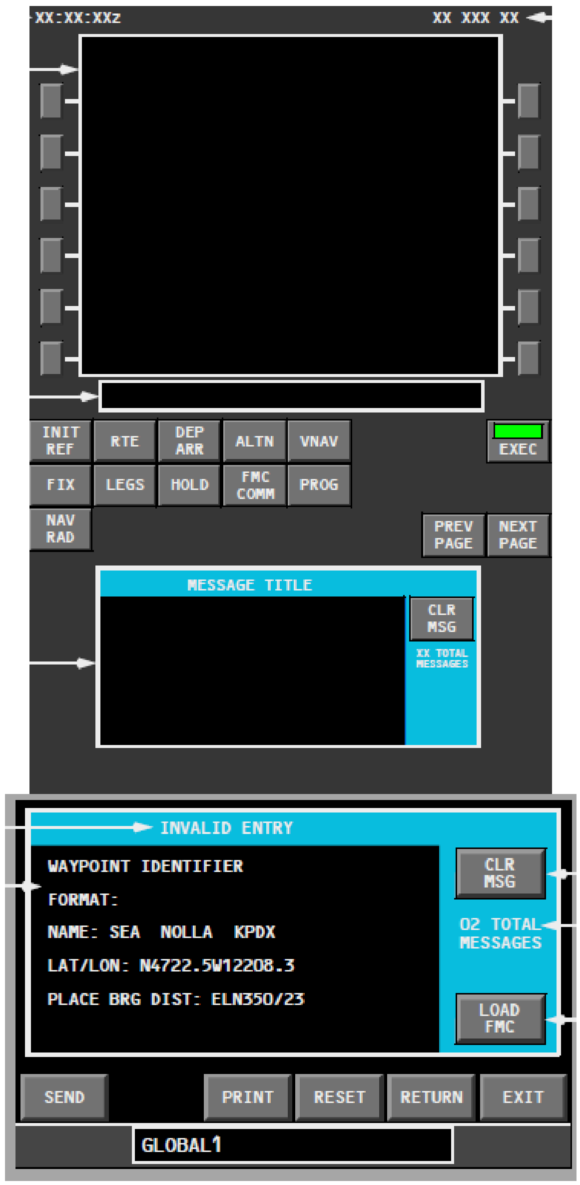

Figure 2-13. B-787 MCDU

An expanded version of the ATC AUX display is shown in Figure 2-14. Besides the ATC clearance and response buttons, the display shows aircraft ID information, Flight Number, UTC time and date. An elapsed timer or chronometer is also displayed. The crews have quick action ATC response keys on the glareshield (Figure 2-11). This is a feature on B777 and B787. The STANDBY key is located on the COMM Manager display on the MFD.

One unique feature of the B-787 is to display altitude and speed prompts in the relevant MCP panel LCD displays. When the crew dials the altitude or speed to match the number in the uplink window, the UL prompt turns green. Likewise, the same parameter in the ATC message window also turns green. This serves as an additional verification that the altitude or speed has been set correctly. These are known as 'DIALABLE' messages. Altitude LCD window on the MCP panel is shown in close up in Figure 2-15.

Figure 2-14. ATC AUX Display

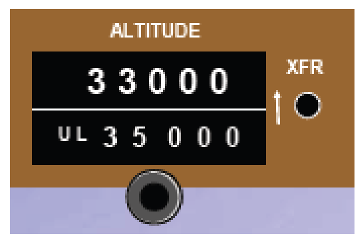

Figure 2-15. MCP Altitude Window

Crew responses to a new incoming ATC Uplink are as follows:

1. A soft chime and a white advisory message "•ATC MSG" appears in the EICAS message field.
2. The ATC Message pops into view on the ATC message block field in the lower left corner of the EICAS display. The ATC message field on the EICAS display also contains soft keys for LOAD, CANCEL, REJECT, and WILCO. Crew can select the soft keys using the discrete cursor or the glare-shield quick response keys. The LOAD prompt must be selected via the cursor.
3. Once the response is sent, the crew verifies that the ground computer has received the message by watching the prompt change from SENDING to SENT.
4. If the ATC clearance contains an altitude or speed, the crew verifies that the dialable uplink in the MCP windows turn green. In addition, the crew should verify that the altitude or speed parameter in the ATC Clearance message (located on the AUX display and in the EICAS ATC Message Block) also turns green.
5. The crew selects the CANCEL key (soft key or glare-shield key). If there are no remaining new unacknowledged ATC messages in the LOG, then the EICAS message block and the "• ATC MSG" advisory on the EICAS message field go blank. The AUX ATC field on the AUX display (outboard of the PFDs) also blanks. This clears the screen for the next incoming message.

2.2.3.1. B-787 and Conditional Clearances

The B-787 will prompt the crew when it is time to enter a conditional clearance. The prompt will display in the message block on the glass MCDU. The FMS will calculate the position on the flight plan for up to five CPDLC conditional clearances. The FMS will also display a circle (ATC circle) at the location closest to the condition on the ND map.

The following conditional clearances are prompted when conditions are met and displayed in the glass MCDU message block:

UM 21 AT [time] CLIMB TO AND MAINTAIN [level]
UM 22 AT [position] CLIMB TO AND MAINTAIN [level]
UM 24 AT [time] DESCEND TO AND MAINTAIN [level]
UM 25 AT [position] DESCEND TO AND MAINTAIN [level]
UM 66 AT [time] OFFSET [distance] [direction] OF ROUTE
UM 76 AT [time] PROCEED DIRECT TO [position]
UM 78 AT [level] PROCEED DIRECT TO [position]
UM 97 AT [position] FLY HEADING [degrees]
UM 118 AT [position] CONTACT [unitfrequency]
UM 119 AT [time] CONTACT [unitfrequency]
UM 121 AT [position] MONITOR [unitfrequency]
UM 122 AT [time] MONITOR [unitfrequency]

2.2.3.2. B- 787/B-777 Data Entry – Error Protection and Recovery

We reviewed Flight Crew Operating Manuals (FCOM) to understand the FMS operations as they pertain to FMS system alerting, range checking, and the ability to either protect against or help to recover (UNDO) from erroneous input. The Boeing models under study (787, 777, 744, and 733) were very similar in the ways they the crew of out-of-range, erroneous, or incomplete data entries. Uniquely, in the B-787, if the pilot enters a value that is out of range or if the data entry contains the wrong syntax, the Boeing 787 presents a 'help' cue to the pilot. This help cue appears on the MCDU glass and cues the pilot to the corrective action needed. Help cues offered on the B-787 are highlighted in blue in the following matrix. The FMS will notify the pilot of a FMS message by annunciating on the EICAS field with a white advisory "•FMS MSG". In addition, the MCDU has a white indicator light that turns on with MSG indicated in the light fixture. The FMS message will display in the scratchpad and in the case of the B-787 and additional HELP messages will appear on the MCDU glass (cyan message box in Figure 2-13)
The Boeing 787 offers several features that help the crew to verify and check data entry:

- FMS messages with displayed help. For example, if crew enter incorrect syntax a "•FMS MSG" white advisory will appear in the EICAS message field. This message will be accompanied by a help message in the MCDU message block shown above in Figure 2-15.
- The FMS generates a conditional clearance prompt for ATC conditional clearances. These 'reminders' will also appear in the MCDU message block shown above. In addition, the FMS will display an ATC circle near the fix or condition for the conditional clearance.
- For LOADABLE messages, the FMS will check over 300 pre-load conditions before displaying a LOAD prompt on the glass MCDU. These pre-load checks are listed in the autoload section (Section 2.4) of the literature review. These pre-load checks verify the ATC clearance against many integrity parameters, including the NAV database. The pre-load checks also verify correct syntax, range (for example OFFSET range) and many other data entry parameters.
- The B-787 has DIALABLE ATC clearances. These clearances such as ALTITUDE, SPEED, FREQ, BARO ALTIMETER, are displayed as prompts in their respective windows on the MCP (in the case of BARO, it will appear on the PFD). When the crew matches the value in the altitude or speed window, then the DIALABLE prompt turns green, as does the value in the ATC clearance located in both the AUX ATC message block and the clearance replicated in the COMM Manager display.

Table 2-1 lists FMS messages that can be displayed to the crew. The EICAS message field displays a "•FMS MSG" advisory in white. The FMC message appears on the glass MCDU. In some cases, the FMC produces a HELP message to cue the crew. These HELP messages are shown in blue in the matrix in Table 2-1.

Table 2-1. B-787 FMS Help Messages

FMS MESSAGE	**Condition** (B-787 HELP messages in blue)
FMC UNABLE RTA	The FMC is unable to reach the RTA Fix at the required time of arrival.
FMC INTERCEPT HDG	LNAV is armed and the aircraft is not on an intercept heading to the active leg.
FMC PERF UNAVAILABLE	Data is missing from the performance fields and performance calculations and predictions cannot be performed by the FMS (usually cost index, gross weight, or cruise altitude).
NAV UNABLE RNP	The ANP (actual navigation performance) is not able to meet the RNP requirements.
CHECK ALT TGT	VNAV Target Altitude and MCP Altitude disagree. Reset MCP or Modify VNAV Altitude Target.
DESCENT PATH DELETED	All Descent Constraints Deleted. Erase MOD or enter new constraint.
DISCONTINUITY	LNAV in HDG HOLD modify active waypoint.
END OF OFFSET	Approaching End of OFFSET. Delete OFFSET or modify active waypoint.
INSUFFICIENT FUEL	Route modification required. More fuel required than available. Modify route.
LIMIT ALT FLXXX	The selected altitude is above VNAV ALT limit. Modify cruise ALT or VNAV target speed
RESET MCP ALT	MCP ALT is set to cruise altitude. Set lower altitude to enable VNAV descent
RTA FIX DELETED	MOD deletes existing RTA fix to retain RTA erase MOD
UNABLE FLXXX AT RTA FIX	VNAV will not attain ALT at RTA fix. RTA time will not be met.
MAX ALT FLXXX	Entered speed or ALT would cause CRZ ALT to be greater than MAX ALT
UNABLE CRZ ALT	Computed TOD is before TOC. Confirm CRZ ALT
INVALID ENTRY	FMC erroneous entry. Recheck entry
INVALID OFFSET	Flight plan MOD caused downpath OFFSET to no longer contain OFFSET legs. Revise flight plan
OFFSET DELETED	Flight plan MOD deleted start of OFFSET. Enter new start waypoint on LEGS page.

2.3. Limitations and Capabilities in the ATC Uplink Message Set

Although, standardization or convergence with common message sets is expected, there are differences in what ATC messages can be accepted by different systems. In this study, we looked at the Mark II CMU, which is a standard configuration on legacy 744 and 737 aircraft. Table 2-2 summarizes the message set commonalities between aircraft systems; it shows that the B-787 and B-777 have a common message set and that the Mark II has a more limited message set.

Table 2-2. Message Commonality between Systems

B787	B777	Mark II
UMs 1-183	UMs 1-183	UM: 0, 1, 3-5, 19, 20, 23, 26-28, 46-48, 51-55, 61, 64, 72, 74, 79, 80, 82, 92, 94,9 6,1 06-109, 116, 117, 120, 123, 133, 135, 147, 157, 159, 160, 163, 165, 171-175, 179,183

Table 2-3 graphically shows what messages the B-787 can display in the Altitude, Speed LCD windows on the MCP and PFD. Altitude, Speed clearances that can be displayed in the MCP are known as DIALABLE messages. The messages show up as prompts in the MCP windows. When the crew dials to the correct altitude or speed value, the prompt turns green, and after a short delay, it blanks out. This action is an additional verification tool for the crew. Frequencies can be sent directly to the radio management unit (RMU) and altimeter settings can be sent directly to the PFD. It is expected that the B-777 will be made common with the B-787 in this regard. In addition, it is planned to include heading values as DIALABLE messages that will display a prompt in the MCP heading window. The blue areas in the table below indicate whether the message can be transferred to the MCP, RMU, or PFD.

Table 2-3. B-787 Message Integration with MCP, PFD and RMU

Uplink Message Number and Element	MCP	RMU	PFD
UM20 CLIMB TO [level]	X		
UM23 DESCEND TO [level]	X		
UM 26 CLIMB TO REACH [*level*] AT OR BEFORE [*timsece*]	X		
UM27 CLIMB TO REACH [level] BY [position]	X		
UM 28 DESCEND TO REACH [*level*] AT OR BEFORE [*timsece*]	X		
UM29 DESCEND TO REACH [level] BY [position]	X		
UM34 CRUISE CLIMB TO [level]	X		
UM35 WHEN ABOVE [level] COMMENCE CRUISE CLIMB	X		
UM36 EXPEDITE CLIMB TO [level]	X		
UM37 EXPEDITE DESCENT TO [level]	X		
UM38 IMMEDIATELY CLIMB TO [level]	X		
UM39 IMMEDIATELY DESCEND TO [level]	X		
UM94 TURN [direction] HEADING [degrees]	X		
UM95 TURN [direction] GROUND TRACK [degrees]	X		
UM98 IMMEDIATELY TURN [direction] HEADING [degrees]	X		
UM106 MAINTAIN [speed]	X		
UM108 MAINTAIN [speed] OR GREATER	X		
UM109 MAINTAIN [speed] OR LESS	X		
UM110 MAINTAIN [speed] TO [speed]	X		

Uplink Message Number and Element	MCP	RMU	PFD
UM111 INCREASE SPEED TO [speed]	X		
UM112 INCREASE SPEED TO [speed] OR GREATER	X		
UM113 REDUCE SPEED TO [speed]	X		
UM114 REDUCE SPEED TO [speed] OR LESS	X		
UM115 DO NOT EXCEED [speed]	X		
UM117 CONTACT [unit name] [frequency]		X	
UM118 AT [position] CONTACT [unit name] [frequency]		X	
UM 119 AT [*timesec*] CONTACT [*unit name*] [*frequency*]		X	
UM120 MONITOR [unit name] [frequency]		X	
UM121 AT [position] MONITOR [unit name] [frequency]		X	
UM 122 AT [*timesec*] MONITOR [*unit name*] [*frequency*]		X	
UM123 SQUAWK [code]		X	
UM 153 ALTIMETER [*altimeter*] [*timesec*]			X

2.4. Limitations and Capabilities in Loadable Uplink Messages

Table 2-4 indicates which messages can be directly loaded into the FMS. If the message contains loadable parameters AND passes the pre-load checks, then a LOAD prompt will be displayed. Work is currently underway to achieve the same loadable message functionality on the Mark II CMU. The blue areas indicate which messages are loadable on different data comm systems.

Table 2-4. Loadable Messages

Uplink Message Number and Element	B787	B777	Mark II CMU
UM46 CROSS [*position*] AT [*level*]	X	X	X
UM47 CROSS [*position*] AT OR ABOVE [*level*]	X	X	X
UM48 CROSS [*position*] AT OR BELOW [*level*]	X	X	X
UM49 CROSS [*position*] AT AND MAINTAIN [*level*]	X	X	
UM50 CROSS [*position*] BETWEEN [*level*] AND [*level*]	X	X	
UM51 CROSS [*position*] AT [*RTAtimesec*]	X	X	X
UM52 CROSS [*position*] AT OR BEFORE [*RTAtimesec*]	X	X	X
UM53 CROSS [*position*] AT OR AFTER [*RTAtimesec*]	X	X	X
UM56 CROSS [*position*] AT OR LESS THAN [*speed*]	X		
UM58 CROSS [*position*] AT [*RTAtimesec*] AT [*level*]	X	X	
UM59 CROSS [*position*] AT OR BEFORE [*RTAtimesec*] AT [*level*]	X	X	
UM60 CROSS [*position*] AT OR AFTER [*RTAtimsec*] AT [*level*]	X	X	
UM62 CROSS [*position*] AT [*RTAtimesec*] AT AND MAINTAIN [*level*]	X	X	
UM64 OFFSET [*specified distance*] [*direction*] OF ROUTE	X	X	X
UM65 AT [position] OFFSET [specified distance] [direction] OF ROUTE	X	X	
UM67 PROCEED BACK ON ROUTE	X		
UM73 [departure clearance enhanced]	X	X	
UM74 PROCEED DIRECT TO [*position*]	X	X	
UM75 WHEN ABLE PROCEED DIRECT TO [*position*]	X	X	
UM77 AT [*position*] PROCEED DIRECT TO [*position*]	X	X	
UM79 CLEARED TO [position] VIA [route clearance enhanced]	X	X	X
UM80 CLEARED [route clearance enhanced]	X	X	X
UM81	X	X	
UM83 AT [position] CLEARED [route clearance enhanced]	X	X	
UM84 AT [position] CLEARED [procedure name]	X	X	
UM91 HOLD AT [*position*] MAINTAIN [*level*] INBOUND TRACK [*degrees*] [*direction*] TURNS [*leg type*] LEGS	X	X	
UM92 HOLD AT [*position*] AS PUBLISHED MAINTAIN [*level*]	X	X	X

The B-787 has a feature that is unique to that airframe model (although B-777 will be made common at some point). The B-787 will send a 'reminder' to the crew that a conditional clearance will soon be required. This will prompt the crew to LOAD the FMS at the appropriate time. This is an advisory message only and is not accompanied by a LOAD prompt. Table 2-5 shows what ATC clearances provide a 'sidelink' or conditional prompt to the crew. The display of the conditional clearance reminder appears in the message block on the MCDU glass display.

Table 2-5. B-787 Conditional UM Notification to Flight Crew

Uplink Message Number and Element	
UM21 AT [*timesec*] CLIMB TO [*level*]	These UMs send a 'sidelink' signal to the display system. Sidelink is an 'aircraft to aircraft' bus signal (sidelink as opposed to a downlink (aircraft to ground) or uplink (ground to aircraft). When the display system receives this conditional clearance sidelink, a prompt box 'pops' up on the active ATC window on the glass MCDU reminding the crew that they are XX.X NM from the fix or position (vertical or lateral). The conditional clearance is also repeated. The display system also puts symbology around the fix or position on the MFD moving map display.
UM22	
UM24 AT [*timesec*] DESCEND TO [*level*]	
UM25	
UM66	
UM76	
UM78	
UM97	
UM118	
UM119	
UM121	
UM122	

The system capability to load ATC clearances directly into the FMS provides benefits to the flight crew. Besides the obvious benefits of reducing pilot workload and error (no ambiguous 'INVALID ENTRY' messages that leave the crew wondering about syntax), the FMS makes approximately 337 integrity checks before it will allow the MFD to display the LOAD prompt. This pre-check removes the burden of the crew having to create proper syntax, range checking of the values, determining whether the flight plan can accept the modifier, and determining whether the fix or procedure is in the NAV database. The FMS accomplishes these tasks for the crew along with other checks to ensure airplane performance and flight plan compatibility with the message parameters. Despite the advantages of this technology, the crew should be trained for a few quirks. For instance, if a concatenated message contains both loadable and non-loadable messages, the loadable messages will activate the LOAD prompt, but the crew must remember to manually load the parameters that cannot be directly loaded into the FMS with LOAD prompt. A representative selection of FMS pre-load checks are given in Table 2-6 as examples.

Table 2-6. FMS Pre-load Checks

Pre-Load Checks	Crew Advantage
The "LOAD FMC" command function is inhibited until the FMF indicates that the uplink is loadable.	The crew is confident that if the LOAD prompt appears, the ATC uplink has passed all pre-load functionality and integrity checks. However, the FMC only looks at the loadable content (parameters). The crew must be aware that in some concatenated message sets, some parameters will have to be manually loaded. This is a training issue

Pre-Load Checks	Crew Advantage
	and should be stated in the aircraft FCOM and be part of the initial training on CPDLC.
The FMF will ignore any non-Loadable elements encountered in the uplink.	This just reinforces the idea that not all parameters are loadable. See comment above.
The [position] in uplink element 74, 75, 79, 83 and the second [position] in element 77, when specified as 'fixname,' 'navaid,' 'placebearingdistance,' or 'airport' will be invalid if not found in the Datalink Flight Plan or the Nav Data Base. The [distanceoffset] variable in uplink element 64 or 65 will be invalid if it is more than 99 nm or in 'distanceoffsetkm.'	Automatic checks of the nav database. Crew does not need to verify NAV database entry. Crew does not need to remember about OFFSET distance rules.
The [procedurename] variable in uplink element 81 will be invalid if it is not compatible with the departure runway or the departure airport if the 'proceduretype' is 'departure,' or with the arrival runway or the destination airport if the 'proceduretype' is arrival' or 'approach.'	This is another crew annoyance with having to remember procedure – runway compatibility. This will now be done automatically by the FMS.
The [altitude] variable in uplink elements 46, 47, 48, 49, 50, 58, 59, 60, 62, 91, and 92 will be invalid if it is equal to or greater than the Cruise Altitude, or if no Cruise Altitude is defined, the maximum certified altitude.	Relieves the crew of having to remember another rule. Also, accompanied by a 'help prompt' to direct the crew to proper entry.
The [altitude] variable in uplink elements 46, 47, 48, 49, 50, 58, 59, 60, 62, 91, and 92 will be invalid if it is not specified in 'altitudeqnh,' 'altitudeqnhmeter,' or 'altitudeflightlevel.'	Prevents erroneous entry of altitude without proper units.
The FMF will build the [time] in uplink message element 52 in a manner consistent with an AT OR BEFORE RTA time entry on the RTA PROGRESS page.	Crew does not have to remember the rule for an RTA entry. FMS with pre-load checks this for the crew. Provides a help response should the pre-load check fail
The FMF will build the [distanceoffset] and [direction] in uplink message element 64 and 65 in a manner consistent with an offset entry on the RTE page.	Provides proper syntax for the crew.
The FMF will build the [altitude] in uplink message elements 46, 49, 58, 59, 60, and 62 to be consistent with an AT altitude constraint entry on the LEGS page at the uplinked [position].	Automatically provides proper syntax sequence and entry for the crew.
The [speed] in uplink message element 56 will be considered invalid if it is less than 100 kts or is not in [speedindicated] format.	Automatic range error checking by the FMs.
The procedure in the uplink element 84 will be considered invalid if the procedure type is a STAR and the STAR is not compatible with the existing Destination Runway.	Relieves the crew of having to determine Procedure–runwaycompatibility. Accompanied by a help message.
If the 'proceduredeparture' is not compatible with the departure runway (if it is runway dependent) or the	Same as above.

Pre-Load Checks	Crew Advantage
departure airport, then the 'proceduredeparture' will be invalid.	
The 'placebearingdistance' will be invalid if the 'distance' is greater than 700 nm.	Relieves the crew of having to remember the rule. Accompanied by a help message
If a duplicate waypoint identifier is contained in the [routeclearance] then the appropriate version of that fix, from the Nav Data Base, will be selected on the basis of the following priority: 1. By the reference latitude/longitude, if included. 2.If it's the first en-route fix and it matches a fix in the departure procedure 3.If it follows an airway and it matches a fix on that airway 4.If it is followed by an airway and it matches a fix on that airway 5.If it's the last en-route fix and it matches a fix in the arrival/approach procedure 6.The one closest to the preceding flight plan fix 7.The one closest to the origin airport (if on the ground) or present position (if in the air)	Prevents the crew from making an erroneous entry from the 'duplicate waypoint' selection box.
The FMF will calculate the position on the Flight Plan of up to five (5) CPDLC conditional clearances.	Benefit to the crew of having conditional clearance reminders.
COMMENT: The FMF will display a circle (ATC circle) at the location of the closest condition on the ND map.	Additional 'insurance.' Conditional clearance limit is shown symbolically on the moving map display.
The CPDLC uplink elements involving conditional clearances will be the following: UM21 AT [time] CLIMB TO AND MAINTAIN [level] UM22 AT [position] CLIMB TO AND MAINTAIN [level] UM24 AT [time] DESCEND TO AND MAINTAIN [level] UM25 AT [position] DESCEND TO AND MAINTAIN [level] UM66 AT [time] OFFSET [distance][direction] OF ROUTE UM76 AT [time] PROCEED DIRECT TO [position] UM78 AT [level] PROCEED DIRECT TO [position] UM97 AT [position] FLY HEADING [degrees] UM118 AT [position] CONTACT [unitfrequency] UM119 AT [time] CONTACT [unitfrequency] UM121 AT [position] MONITOR [unitfrequency UM122 AT [time] MONITOR [unitfrequency]	Lists the conditional clearances that will provide a memory prompt to the crew.

If a clearance passes the Pre-Load check then an ATC Clearance box will appear on the MCDU glass with a LOAD FMC button (Figure 2-13).

The newer the FMS, the more messages that are loadable. The trend is for FMS to be able to load more CPDLC messages. As the technology matures, the push will be to allow more and more ATC clearance to be loadable. It is envisioned that conditional clearances will be loadable once the aircraft nears the clearance limit. General rules will apply as follows:

- EXPECT clearances are not loadable, only clearances with full authority.
- Clearances occur only when the action on the FMS is straightforward— is FMS loadable; for instance, UM 19 “MAINTAIN [level]” is not FMS-loadable because it’s not clear whether this is a change to the cruise altitude or only an intermediate clearance.
- The current state of loadable messages is exemplified by Table 2-7 [104]. The newer the platform, the more messages can be loaded into the FMS. On the Boeing side, it is expected that the 737NG, 777, and 787 will reach commonality with the loadable message set. The same is true of the Mark 2 CMU that is configured for legacy 737 and 747 aircraft.

Table 2-7. Loadable Message Set by aircraft model

Uplink Message Number and Element	A340	747	777	787	737
UM46 CROSS position AT level			X	X	
UM47 CROSS position AT OR ABOVE level			X	X	
UM48 CROSS position AT OR BELOW level			X	X	
UM49 CROSS position AT AND MAINTAIN level				X	
UM50 CROSS position BETWEEN level AND level				X	
UM51 CROSS position AT time	X	X	X	X	X
UM52 CROSS position AT OR BEFORE time	X	X	X	X	X
UM53 CROSS position AT OR AFTER time	X	X	X	X	X
UM56 CROSS position AT OR LESS THAN speed				X	
UM58 CROSS position AT time AT level				X	
UM59 CROSS position AT OR BEFORE time AT level				X	
UM60 CROSS position AT OR AFTER time AT level				X	
UM62 AT time CROSS position AT AND MAINTAIN level				X	
UM64 OFFSET distance direction OF ROUTE		X	X	X	X
UM65 AT position OFFSET distance direction OF ROUTE				X	
UM67 PROCEED BACK ON ROUTE				X	
UM73 pre-departure clearance		X	X	X	X
UM74 PROCEED DIRECT TO position		X	X	X	X
UM75 WHEN ABLE PROCEED DIRECT TO position			X	X	
UM77 AT position PROCEED DIRECT TO position		X	X	X	X
UM79 CLEARED TO position VIA route clearance	X	X	X	X	X
UM80 CLEARED route clearance	X	X	X	X	X
UM81 CLEARED procedure name			X	X	
UM83 AT position CLEARED route clearance	X	X	X	X	X
UM84 AT position CLEARED procedure name				X	
UM91 HOLD AT position MAINTAIN level INBOUND TRACK deg dir				X	
UM92 HOLD AT position AS PUBLISHED MAINTAIN altitude				X	

2.4.1. Automation Philosophies with ATC Uplinks

Although, automation philosophies vary among vendors, one major supplier of data comm software shared philosophies for ATC uplinks.

Automation must be provided for uplink messages under these circumstances:

- Loading of CPDLC clearance messages into the FMS (i.e. not including any EXPECT messages) includes a [routeclearance] parameter
- Resolution of duplicate names for any [position] parameter in a CPDLC uplink, including use of any optional latitude/longitude in the uplink
  - Note: Any ATS changes that are autoloaded into the FMS will include flight crew capability to review, activate, and execute.

Automation is recommended for uplink messages under these circumstances:

- Monitoring "conditional" clearances and alerting, to preclude early/late execution of the clearance
- Auto-tuning radios (i.e. Frequency/Channel) for "contact" and "monitor" instructions to support ATC voice communications.

Automation that should NOT be provided to minimize the possibility of crew errors:

- Loading of CPDLC clearance messages including "EXPECT" into the FMS
- Loading of conditional clearances into other systems (e.g. FMS, autoflight) in such a way that they could affect the airplane trajectory prior to the condition being satisfied

2.5. Current Data Comm Equipage—Limitations and Capabilities

Existing CPDLC systems vary in limitations and capabilities and mixed equipage is the norm for U.S. air carriers. The summaries below are by model type and exemplify the data as of 2010.

2.5.1. Boeing 737 NG and 737 Classic Aircraft Equipage

There are currently 1,293 B-737 aircraft owned and operated by U.S. commercial operators [42]. Of these, 829 model 737-600/700/900 aircraft are currently in production and referred to as 737 NGs. The other 464 aircraft are 737-300/400/500 models, referred to as 737 Classics, and are no longer in production. The Boeing 737 uses a federated ACARS system to perform the AOC CPDLC function on the aircraft. The ACARS system is buyer-furnished equipment, selected by the airline operator. The FMS is standard on the 737 aircraft and is manufactured by General Electric's (GE) avionics division, formerly a division of Smiths Industries. Three VHF radios are installed for CPDLC-equipped aircraft. Airlines that do not install CPDLC equipment typically install just two VHF radios for voice operation. The flight crew interface is via ARINC 739 MCDUs.

Legacy 737 aircraft 737-300/400/500 do not come equipped for full datalink capability and the effort to upgrade may not be cost-effective [42]. The FMS installed on these aircraft is not made by Honeywell. Hence, it is not known if the FMS can be upgraded to support FANS 1+ capability. 737 classic aircraft that were delivered with AOC Datalink capability will require that at least the third VHF radio be upgraded with VDL Mode 2 capability or be replaced with one that supports VDL Mode 2. The CMU will also need to be upgraded with VDL Mode 2 capability or replaced with one that includes that capability. The wiring for 429 buses between CMU and VHF radios and Mode S transponders will need to be added. Since the third VHF radio and AOC Datalink were options on 737 classic aircraft, there may be some aircraft that will require adding the third VHF radio, a third RCP and a CMU with all their associated wiring.

2.5.2. Boeing 747-400, 757 & 767 Equipage

1,046 B747-400, B757 and B 767 aircraft are currently owned and operated by U.S. commercial operators [73]. Of these, 848 are passenger aircraft and the remaining 198 are used as freighters. The Boeing 747-400, 757 and 767 also use a federated ACARS system for performing the AOC Datalink functions on the aircraft. The ACARS system is a buyer-furnished piece of equipment selected by the airline operator. The FMS is standard on the 747-400, 757, and 767 aircraft and is manufactured by Honeywell. Three VHF radios are installed on 747-400, 757, and 767 aircraft. Most of these aircraft have AOC CPDLC capability. The flight crew interface is via ARINC 739 MCDUs. 747-400, 757 and 767 aircraft currently in service are equipped either with ARINC 750 VHF data radios that do not have VDL Mode 2 capability but which are upgradable to VDL Mode 2 or ARINC 716 VHF radios which support data Mode 0 but which are not upgradable to support Mode 2. The 747-400, 757, and 767 aircraft are equally likely to be equipped with CMU Datalink avionics or older ACARS Management Units (MUs) all of which support AOC and ARINC 623 ACARS applications. The 747-400 aircraft have Honeywell Pegasus Flight Management Systems with FANS 1+ capability or with FANS 1+ applications that can be enabled. 757 and 767 aircraft may be equipped with a Pegasus FMS that has FANS 1+ capability or can be upgraded with a Pegasus FMS. Because the 757 and 767 are out of production and the 747-400 will be replaced with the new 747-8 in late 4Q 2010, the possible avionics upgrade configurations to equip these aircraft with ATC data comm capability will be different and are described separately, below. More specifically, upgrades to full SC-214 data comm functionality for the 757 and 767 are not addressed, as it is not likely that any meaningful numbers of these aircraft will be in service beyond 2018.

2.5.3. Boeing 777 Equipage

Currently, 135 Boeing 777 aircraft are owned and operated by U.S. commercial operators. The Boeing 777 uses an integrated modular avionics (IMA) architecture called AIMS that hosts a number of software applications, including flight management functions (FMF) and communications management functions (CMF) that include AOC as well as FANS 1+ CPDLC. The AIMS system is manufactured by Honeywell and is standard on all 777 aircraft. The original AIMS system, called AIMS 1, was installed on aircraft thru Oct 2003. Starting in Oct 2003, a new version of the AIMS system, called AIMS 2, was cut into the Boeing production. The flight crew interface is via Displays that are integrated in as part of the AIMS system. The COM radios are federated ARINC standard radios with multiple suppliers. All B777s have three VHF radios installed. Older 777 aircraft with AIMS 1 avionics are equipped with ARINC 750 VHF radios, which do not have VDL Mode 2 capability but can be upgraded to support Mode 2. Newer 777 aircraft that have AIMS 2 avionics should be equipped with ARINC 750 VHF radios which have certified VDL Mode 2 capability. **Boeing 777 current CPDLC configuration:** All B777's have a CMF with AOC, ARINC 623 and FANS 1+ AFN and CPDLC applications incorporated. However only those that have AIMS 2 avionics have certified VDL Mode 2 capability.

2.5.4. Boeing 747-8 Equipage

The 747-8 is a new version of the Boeing 747 wide body jumbo jet that will enter into service in late 2010 or early 2011. There is a passenger version and a freighter version. The majority of the orders on the books are for the freighter version—only two airlines having placed orders for the passenger version. The Boeing 747-8 retains the federated ACARS system for performing the AOC Datalink functions on the aircraft and a federated FMS that performs the ATC Datalink functions. The ACARS system is furnished by Collins. The FMS is manufactured by Honeywell. Three VHF radios are installed on 747-8 aircraft. Most of these aircraft have AOC CPDLC capability. The flight crew interface is via ARINC 739 MCDUs. 747-8 will be equipped with ARINC 750 VHF data radios that have VDL Mode 2 capability. **Data Comm avionics architecture:** VHF radio configuration: **CPDLC configuration and application:** The CMU Datalink avionics will support AOC and ARINC 623 ACARS applications and will have VDL Mode 2 and ATN Router functionality as standard features. **FMS configuration:** 747-8 aircraft will be equipped with the Honeywell Next Gen (NG) FMS Systems with standard FANS 1+ capability and optional Link 2000+ CPDLC applications. The baseline and possible ATC data comm-upgraded configurations for the 747-8 are discussed below. **Link 2000+ and FANS 1+ only architecture:** The 747-8 baseline data comm configuration will include FANS 1+ applications and VDL Mode 2 CPDLC capability. Link 2000+ CPDLC applications will be a selectable optional feature that includes the full ATN router and end system stacks in the CMU. Full SC-214 WP1 & WP2 and FANS 1+ data comm architectural upgrades: The 747-8 data comm functionality will be upgraded to full implementation of SC-214 WP1 and WP2 applications by means of a software update to the NG-FMS.

2.5.5. Boeing 787 Equipage

The Boeing 787 is a new wide-body passenger jet replacement for the 767 that will enter into service in late 2010 or early 2011. Data Comm avionics architecture: The Boeing 787 uses an IMA architecture called the Common Computing System (CCS) that uses ARINC 664 AFDX buses and switches to interface to radios and displays. The CCS hosts a number of software applications including the FMF and CMF that include AOC as well as FANS 1+

CPDLC. The CCS is manufactured by GE (formerly Smiths Industries) and is standard on all 787 aircraft. The flight crew interface is via displays that are integrated in as part of the CCS. VHF configuration: The COM radios are federated ARINC standard radios supplied by Collins. All B787s have three ARINC 750 VHF radios which have VDL Mode 2 capability. **Datalink configuration and applications:** All B787's have a CMF with AOC, ARINC 623 and FANS 1+ CPDLC applications incorporated as standard functionality. **FMS configuration:** The FMF function provides all the necessary data for the ATC data comm functionality hosted in the CMF.

2.6. New Enabling Technology Developments

New technology developments have the potential of enabling the use of CPDLC in other phases of flight while maintaining an equivalent level of safety with the 'See and Avoid' concept and reducing separation requirements. In general, the trend in display technology is towards panoramic, graphical, 3D technology, moving the display technology to a head up location. For display locations in the forward field of view (front panel location) the trend is to provide graphical 'quick look' formats that allow the pilot to quickly assess aircraft situations with a minimum of head-down time. This philosophy and intended function can be seen in airport moving map technology with taxi route clearance overlays, integrated data driven charts and maps, traffic awareness (TCAS, ADS-B, TIS) integration with moving map displays, etc. OLED windshield displays, HUDS, and near-to-eye technology are slowly moving surface movement and text messages to a head-up view. new Oceanic In-trail, airport surface movement, FIM-S (merging and spacing) CDTI displays, and near-to-eye technology will not only provide greater situation awareness (SA) but also reduce the amount of head-down or head-away time on the flight deck.

2.6.1. Oceanic In-trail Display Technology

Oceanic In-Trail Procedure (ITP) will increase the opportunities for flight level (FL) changes that would otherwise be blocked due to standard separation requirements. The ITP employs new, onboard avionics equipment that provides crews with improved information about nearby traffic and new procedures that enable crews, when appropriate criteria are met, to request an ITP FL change referencing one or two of the nearby aircraft that might otherwise block the FL change. The ITP equipment uses ADS-B IN data broadcast from nearby aircraft that provides more accurate position data than is available to oceanic controllers, thus enabling controllers to approve ITP FL change requests that reference these aircraft, even if standard separation would not otherwise exist with these reference aircraft. In other words, the availability of more accurate airborne surveillance data enables safe FL changes through intervening FLs with lower separation minima than when using current ground-based non-radar separation rules. Other benefits of ITP are:

- Reduced fuel burn and carbon dioxide emissions because aircraft have more opportunities to reach the optimum FL or an FL with more favorable winds
- Increased safety because aircraft have more opportunities to leave a turbulent FL, thus reducing passenger injuries
- Less need to carry excess fuel reserves

The Honeywell ITP system (Figure 2-16) is comprised of one traffic computer, two transponders, and two Goodrich EFBs, each able to run an ITP display. The ITP displays accept commands through a touch screen user interface (with no "hard" controls), use traffic computer data almost exclusively, and do not provide feedback to any avionics system on the aircraft. Not providing feedback to other avionics systems implies any information passing from the ITP displays to other aircraft displays must be entered manually by the flight crew (e.g., Controller Pilot Data Link Communications (CPDLC) clearance data).

Figure 2-16. Example of the ITP display on a Goodrich EFB.

2.6.2. Cockpit Display of Traffic Information (TCAS, ADS-B, TIS)

CDTIs under development will allow the display of TCAS, ADS-B, and TIS traffic (Figure 2-17). Traffic symbology will be integrated with AMM displays and also allow the overlay of other map layer features such as Uplink WX, RADAR, etc. It is envisioned, and in fact in development, that CDTI, AMM, FIM-S, will be integrated into a single moving map format—albeit with different support symbology. Colors and symbols are used to distinguish ground from air traffic. Further differentiation is applied to separate TCAS, ADS-B and TIS traffic.

The example CDTI in Figure 2-18 shows the moving map display zoomed in on an airport location. Traffic and weather can be displayed in relationship to the airport layout. The map can be oriented to either a heading-up or north-up format. Ground traffic can be displayed on the airport surface. If traffic is occupying a runway, color effects (usually red) are used to show an occupied runway.

Figure 2-17. NASA CDTI Concept

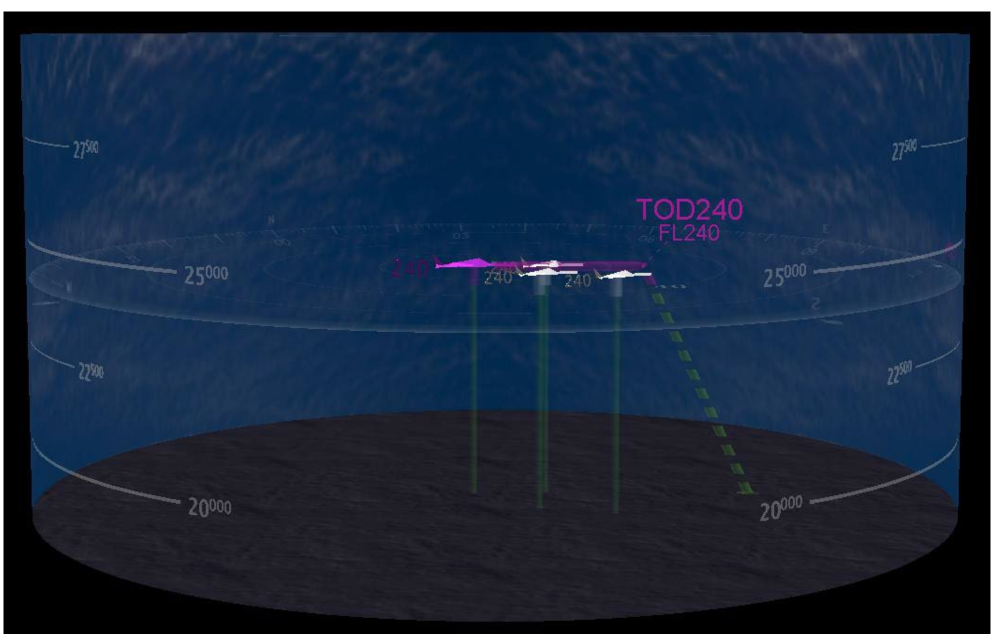

Figure 2-18. NASA CDTI Concept Sideview

2.6.3. Airport Moving Map Displays

The technology for airport moving map (AMM) displays is rapidly advancing. An example is shown in Figure 2-19. Both 2D and forward-looking perspective displays are being developed. AMMs are data-driven charts that can obtain data from several data base resources. Application of these databases allows rendering of buildings, hazard areas, NOTAMS, signage, and taxi-runway 'paint.' Sensors make it possible to display ADS-B surface traffic as well as linked radar display of other traffic. Taxi clearances can be portrayed as a layer on top of the map giving clear and unambiguous guidance to the crew. The displays are being developed for forward field of view and will eventually migrate to head-up technology. One of the intended functions of these moving map displays is to allow a 'quick look' and assessment of the surface situation. The implication for datalink is that clearances will be graphically portrayed, requiring less head-away or head-down time for the pilot. Airport moving maps can be integrated within the navigation moving map display on the MFD. This integration has several advantages, including the ability to add other map layers as well as FMS data. Flight plan information, uplink weather, geographical data, etc. can be added as layers. Zoom out capability allows users to see an extended flight plan or just the initial departure, radar returns, uplink weather in the airport vicinity; they can zoom in to gather further detail on the airport environment (at low ranges, surface signage and paint will become visible). AMMs integrated with MFD moving map displays also allow panning, aircraft centering, map orientation modes to be set. AMMs will be a key technology enabler for surface CPDLC.

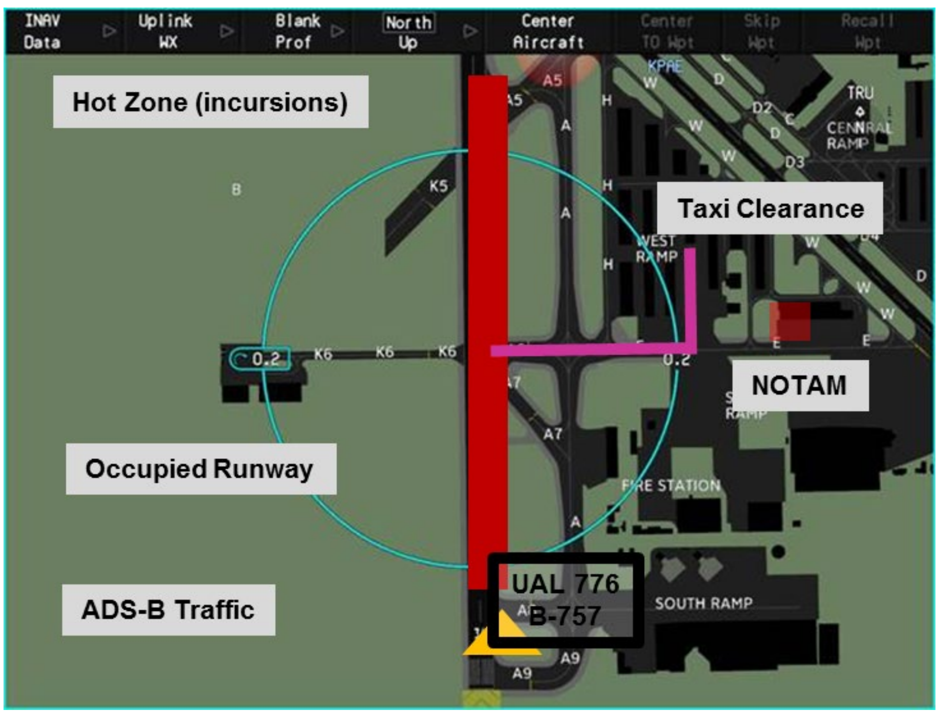

Figure 2-19. Airport Surface Moving Map Displays: FAA OP-Eval-2

2.6.4. FIM-S Decision Aiding Displays

Displays supporting FIM-S operations aid the pilot with merging and spacing on target aircraft (Figure 2-20). Eventually these displays will be integrated with AMM display symbology formats so that other overlay features can be included. As with AMM displays or data driven charts, FIM-S displays will aid the pilot, quicken pilot decisions, and allow the graphical overlay of CPDLC clearances. All these features will help to reduce overall pilot response time.

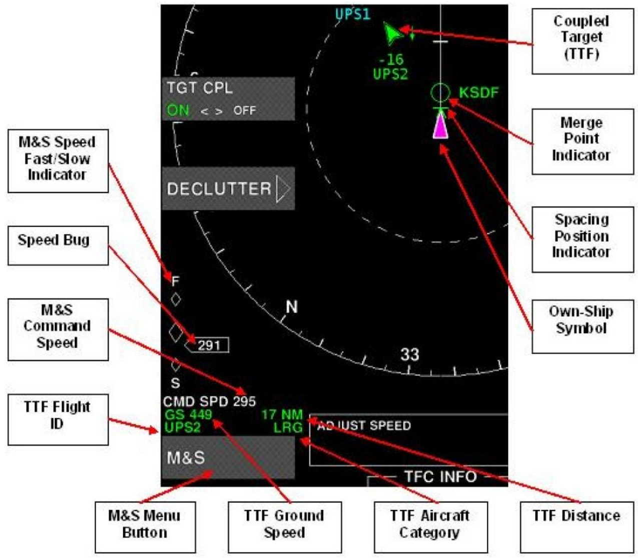

Figure 2-20. NASA-Ames Research Center – FIM-S prototype

2.6.5. Integrated Chart Data

Data-driven charts integrate chart procedures (arrivals, departures, and instrument approach procedures) with the moving map display. Integration of the procedure chart information allows the pilot to keep eyes forward without having to scan a chart (paper or electronic). The integrated chart information can be de-cluttered as necessary while allowing the overlay of other map features such as Uplink WX, RADAR, TCAS, ADS-B, geopolitical boundaries, airways, special use airspace, TERR, and more. Integration with CPDLC is possible (with taxi clearance overlays, graphical portrayal of new clearances, etc.). The overall flight deck effect will be to quicken pilot decision making while reducing overall workload.

The example in Figure 2-21 shows what is currently offered on some platforms. This electronic representation of an instrument procedure is an electronic version of a paper chart. The chart 'viewer' is essentially a PDF viewer that allows the chart presentation to be displayed on a forward MFD.

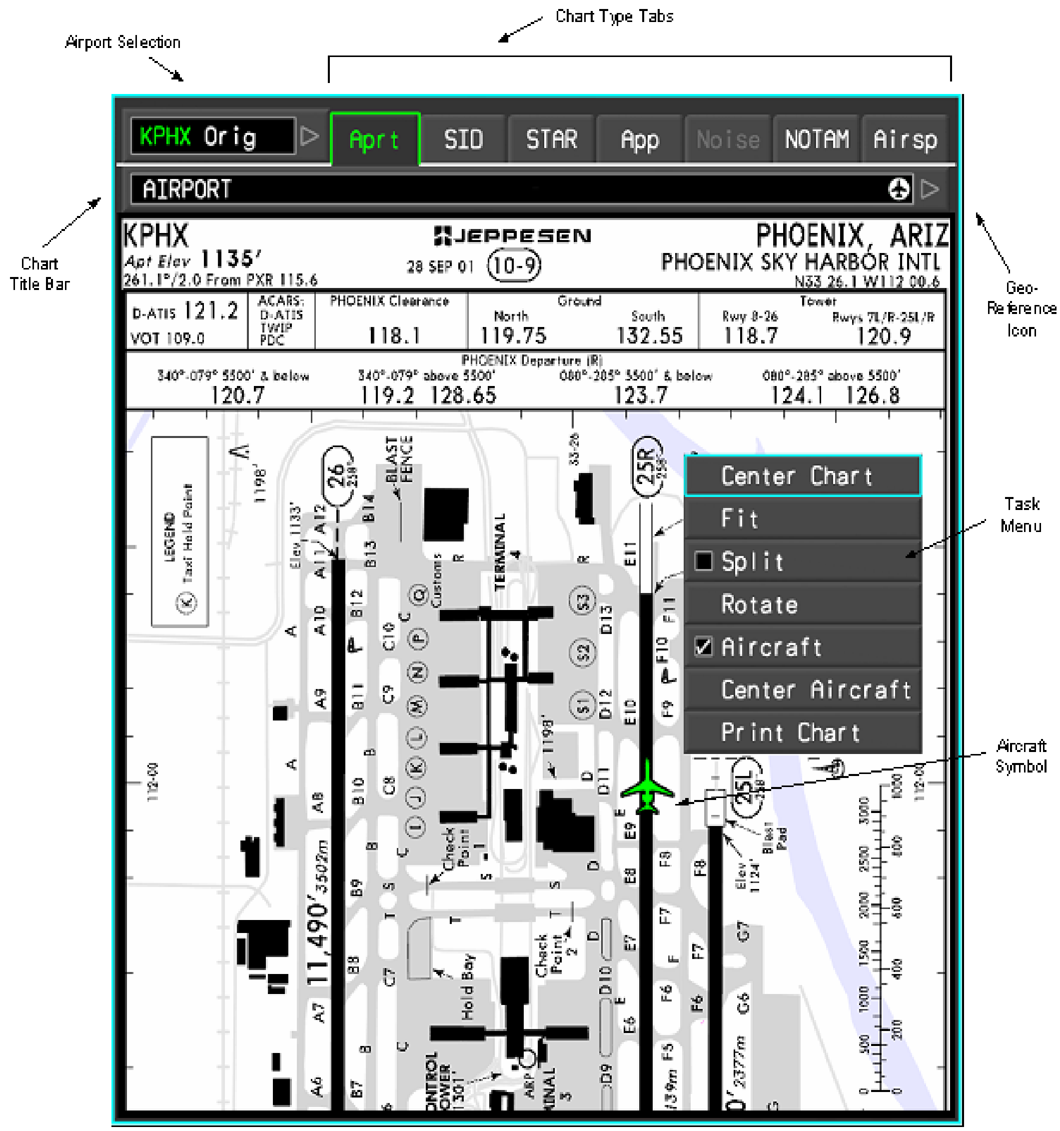

Figure 2-21. Current charts offering

In Figure 2-22 chart information has been integrated with the moving map display to show airways. For IAPs, DPs, or ARVs, courses, altitudes, notes, and other information can be attached to the procedure leg along with other tactical information such as MSA, MAP, and MINs.

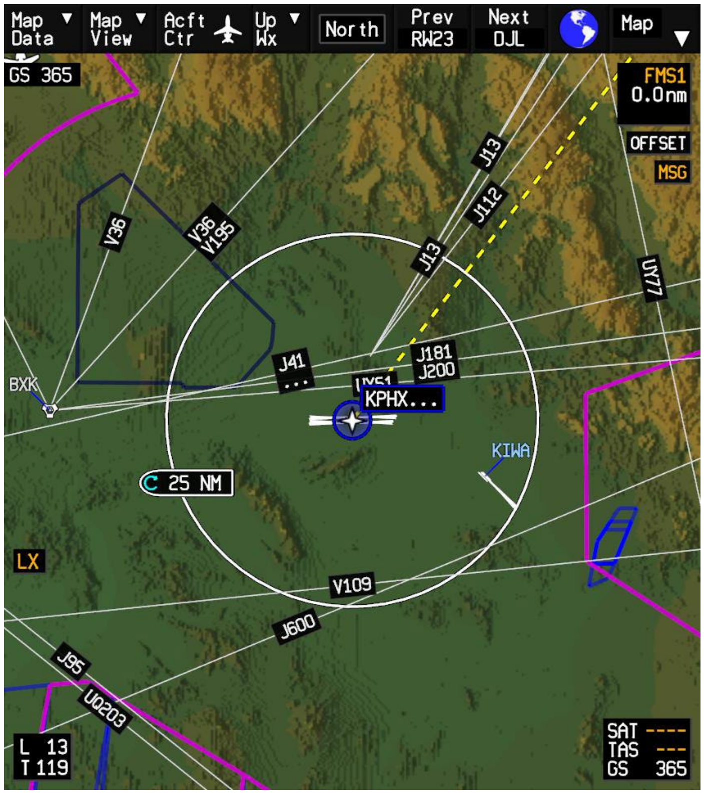

Figure 2-22. Example integrated enroute chart

2.6.6. Near-to-eye Technology

Near-to-eye technology has proven itself in flight tests and other domains. Figure 2-23 is an example of a head-mounted display. The head-mounted assemblies are getting lighter, more comfortable, with enhanced FOV and color. Display of text, vectors, and color graphics will enable the display of some CPDLC messages in a head-up, forward-field, collimated view. Display visor information can be controlled with a yoke-mounted discrete cursor that allows quick activation of modes, CPDLC responses, etc.

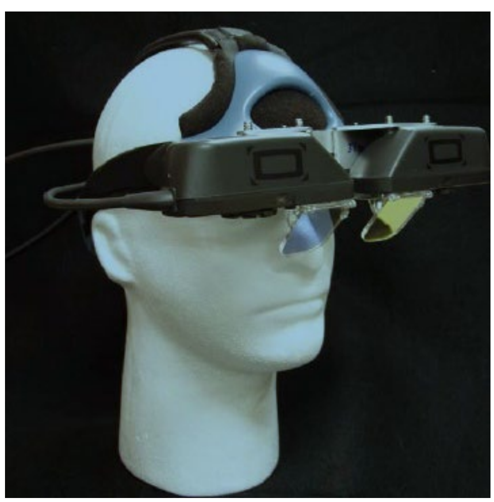

Figure 2-23. Example of a head mounted display
(*Proceedings of the 2009 SPIE Defense, Security, & Sensing*.
Orlando, FL 13-17 April 2009)

2.7. CPDLC Limitations and Capabilities Implications for Crew Procedures

The main results of the study reported in [75] indicate that mixed (CPDLC) equipage operations are feasible, to a limit, within the same airspace. The higher the traffic density of equipped aircraft, the lower the number of unequipped aircraft that can be managed within the same airspace. This is logical, because higher traffic density in the same volume reduces the degrees of freedom or maneuver options for conflict resolution. Under such conditions, the controller workload also increases. From the flight deck side, it is important for the controller to be aware of the capabilities of each aircraft so as not to send clearances that cannot be complied with, which would result in the flight crew rejecting clearances or resorting to negotiation—both choices could lead to slowdowns in the system. As CPDLC becomes the norm in far-term NextGen, the limitations due to mixed equipage will be reduced.

The Boeing 787 provides 'sidelink' prompts for conditional clearances to remind the pilot when the condition is met. The Boeing 777, 744, and 733 do not have this capability. The Boeing 787 CPDLC control interface uses a free and a discrete cursor, while the B777 uses a free cursor only and requires more keyboard activity. Keyboard response times are faster than cursor-driven controls [64]; however, keyboard data entry may have greater numbers of input errors. The B744 and B733 require manual clearance input, while the B787 and B777 allow UMs to be loaded into the FMS and/or MCP. The B787 allows loading directly into the MCP ALT window while the B777 does not. Preview and performance predictions can vary depending on FMS type and model.

None of the aircraft models reviewed can perform RTAs in climb or descent; however, several RTA prototypes on different platforms, B757 and A320 in particular, are being developed to perform RTA in climb or descent phase.

The identified limitations and capabilities have implications for CPDLC procedure development. In addition to developing procedures that address these limitations and capabilities, analyzing current flight deck procedures will also show the potential CPDLC introduction issues.

The following are the main implications for CPDLC crew procedures:

- ATN and FANS message sets across models has not been standardized, but convergence on a common set is expected.
- Autoload capability across model types is variable and limited. This is expected, but will eventually be standardized as requirements become known.
- Conditional clearances in the newer models have a sidelink prompt that displays the clearance to the crew as they near the clearance limit.
- The different HMIs suggest the pilot response time may vary, especially with those configurations allowing loadable elements. This idea will be validated in Phase II of this project in a full mission LOFT scenario.
- The STANDBY response key is located on the ACTIVE or NEW MESSAGE page format on the Mark 2 CMU. On the B-777 and 787 it is located on the COMM manager. It is not known how frequently this response type will be used. It was noticed anecdotally that some complex clearances (those requiring an extended crew discussion on aircraft performance) required the use of a STANDBY response while the crew discussed the clearance.
- On the B-787 and B-777, if the crew does not clear the last ATC message from the displays, salience will be lost when a new message arrives. What is lost is the 'pop-up' effect of the "•ATC" advisory on EICAS and the 'pop-up' effect of the message block. Although the chime will sound with the new message, some attention-getting attributes will be lost if the previous message is not cleared.
- New display technology such as near-to-eye, AMM displays, and FIM-S displays will help to reduce overall pilot response time with ATC clearances. The CPDLC HMI interfaces and the ability to 'autoload' messages is only part of the solution. Quickening pilot evaluation of a clearance (decision aiding) must be part of the solution to reduce response time, reduce flight technical error, and reduce pilot error while enhancing error recovery.

2.8. CPDLC Procedures

ATC Operational Guidance for LINK2000 Services [30] describes controller procedures. Similar procedures for flight deck CPDLC tasks must be developed and standardized. To an extent, this has been accomplished (for example [55]); this study extends this further by specifically analyzing each individual UM for procedure implications.

History has proven the necessity of procedural discipline [29]. In a 1987 study of 93 hull losses, pilot procedural non-compliance was stated as a significant factor in over 33% of the accidents. Similar results were reported by Duke [29] in his analysis of 21 turbojet Part 121 accidents. Lack of procedural training or SOPs accounted for 69 percent of crew errors — more than three times larger than the second ranking category: decision making. In 1991 Boeing concluded a 10-year study that showed that flight crew deviation from established procedures contributed to nearly 50 percent of all hull-loss accidents [7].

2.8.1. General Considerations

This section is reviews the development and use of procedures in normal situations. Procedures are used as prescribed action lists to help human operators remember and follow mandatory steps that enhance safety, workload and performance criteria [13]. The review identifies ways of improving the design of CPDLC procedures based on a human-centered approach and ways to contextualize and operationalize CPDLC procedures training. Note that the use of procedures for non-normal and emergency situations is outside the scope of this project.

The results of [26] help in understanding how pilots follow procedures dictated by management philosophy and policy embodied within flight deck procedures. The paper suggests that new perspectives on design may be required to support the design of procedure and the definition of the pilots' role.

Although procedures can mitigate negative system effects and bias the crew towards correct action, they cannot by themselves guarantee compliance with the ATC clearance. Flight discipline [12, 56], good crew resource management (CRM) [68], and support by an airlines philosophies and policies [19] are also important. Crew call-outs and crew briefings for pre-flight, takeoff, departure, and arrival phases also play an important role in mitigating the weaknesses of CPDLC while enhancing its strengths. For instance, crew briefings establish the roles and responsibilities for both the flying pilot and non-flying pilot or pilot monitoring. The crew briefings can take into account special circumstances and provide expectations for the use of voice versus CPDLC.

With respect to CPDLC, procedures help in the following steps or tasks involved in CPDLC: retrieval, reading, comprehension, planning, and execution [25]. Factors such as lack of training, over-generalization, or inadequate knowledge may lead to wrong decision rule selection, deduction failure, condition or side-effect not considered, or induction failure. Other pilot needs that should be addressed by procedures include:

- Pilots need to understand the nature of a situation before acting; procedures should be designed to support understanding of the implications of clearances; procedures should support rationale of prescribed actions and their consequences; training should enable pilots to better acquire situation patterns in order to anticipate the right actions in the right situations.
- Pilots should control the situation at all times, i.e., they should be informed of the effects of their actions at all times and the repercussions of prescribed actions.
- Pilots should see the status of tasks that have been performed.

2.8.2. Pilot Task-related Factors

Reference [13] classifies task-related causes of inappropriate or incorrect situation awareness as:

- *Incorrectly timed actions*: delays, omissions or premature actions. Applied to CPDLC, these actions imply delays in acknowledging or replying to UMs, omissions of message elements, or premature execution of conditional clearances.
- *Actions out of sequence*: jump forward (omission as a special case), jump backward, or repetition. Applied to CPLDC, these actions refer to the sequence in which CPDLC messages are handled. Procedures should support

pilots to identify out-of-sequence UMs. Not following procedural steps sequentially, for example reading out a message before analyzing, could also result in problems.
- *Incorrect actions*: branching, intrusion or side tracking. These issues apply to CPDLC procedures in the form of distractions and interruptions while performing CPDLC tasks.
- *Incorrect duration*: too long/short duration. Relative to CPDLC, incorrect duration applies to conditional clearances in which flight crew should wait for required conditions to be met before execution of clearances.

Applicable suggestions for improved human-centered design of CPDLC tasks and procedures from [13] are:
- Anticipate repercussions of the execution of checklists at design time: This concept is particularly important to CPDLC use in terminal areas and in high-workload phases of flight.
- Reduce the sharing of checklist action items among crew members: In current checklists, action items are overly shared by crew members, which may cause errors.
- Clearly indicate executed procedure steps and items on the screen (for example, in green color and using a prompt): This concept applies more to CPDLC message lists than procedures, unless electronic procedures are used.

2.8.3. Intra-cockpit Communication, Cooperation, and Coordination

Intra-crew communication for shared awareness is a 'backbone' for any CPDLC procedure. CPDLC technology increases the need for intra-crew communication [68]. The changes introduced by CPDLC influence the relationship between the pilot flying and pilot monitoring.

In particular, it is important to verbalize the ATC UM to avoid entering and accepting a clearance without proper evaluation by both crew members. Good CRM demands that crewmembers communicate and evaluate a clearance prior to responding (some simple clearances may be exceptions).

Other benefits to establishing disciplined intra-cockpit communication include:
- Requiring structured communication for CPDLC promotes good teamwork [73, 74, 71] as communication degrades under poor cockpit discipline.
- CPDLC procedures promote and engage the role of the PM pilot and can prevent the pilot monitoring (PM) from becoming removed or complacent about cockpit duties [73]—when the workload suddenly increases, the PM may be too far out of the loop to be of any assistance [73].

When designing intra-crew procedures the impact on ATC operations should be considered. Mixed equipage, mixed communications (voice and CPDLC), and mixed procedures (tailored arrivals versus standard arrivals) is increasing the workload for ATC controllers. Recent trials of tailored arrivals into the Miami area were observed as part of this research. It was evident that some airline procedures placed a burden on the controller. For example, the controller had to safely separate and smooth traffic with aircraft that had different modes of communications, different expectations, and different performance profiles [Appendix D – ZMA and MIA TRACON Observation].

Pilot training should emphasize systematic information cross-checking. Each crew member should clearly understand what his or her role is and the repercussions of his or her actions. Important information should be cross-checked to avoid situations were delegation is not clearly understood or where there are conflicting priorities or a management problem.

2.8.4. Operational Interviews

We conducted operational interviews to explore current ground and cockpit procedures with ACARS and ATC clearances. We interviewed several pilots and MIAMI TRACON to understand both ground and air side ATC-flight deck coordination.

2.8.4.1. Airline Interviews

All the pilots interviewed had check airman and/or a flight standards background. The aircraft (in all cases) were ACARS equipped. The ACARS unit was used for PDC (pre-departure clearances), ATIS, Weight and Balance

Numbers, and limited FIS). This was noteworthy as it described how ACARS was used not only at the gate but also the ramp and initial taxi. None of the airlines were equipped with CPDLC nor were they contemplating equipage in the near term. Nor were any of the carriers, flying international oceanic routes with CPDLC.

The structured interview used a phase of flight approach that began with pre-departure activity at the gate and ended with an approach phase of flight. One focus was the Captain's and First Officer's tasks and responsibilities with regard to ACARS and ATC Comm during the ground phase, and how their tasks and responsibilities changed during flight for the PF and PM. The pilots were encouraged to talk about procedures and also about how the procedures could be impacted by unanticipated events. Also, the pilots were encouraged to discuss CPDLC as the primary means of communication during all phases of flight and how CPDLC would integrate (or not) with other pilot tasks.

The output from these interviews fed into this paper's recommendations for CPDLC crew procedures and procedural compliance with CPDLC. When constructing the phase of flight approach for CPDLC procedure recommendations, it seemed logical to populate the phases of flight with all crew tasks (checklists, calls, flows, and other flying and non-flying tasks) so that a realistic context could be built when discussing specific CPDLC procedures.

Although the responses from the airlines varied, all pilots found agreement with some threads. These areas of agreement are listed below, along with other interesting comments.

- The PDC (pre-departure clearance) is requested and received by the ACARS unit at the gate. The clearance was usually requested after the safety checks and ATIS. Either pilot could request the PDC depending on circumstances. However, SOP for both airlines was to check the PDC against the paperwork— this was done by both pilots. The clearance was entered into the FMS (either pilot depending on circumstances). SOP, however, was to have each pilot verify the FMS entry, check the entry against the PDC, and check that proper settings were made for departure (e.g. initial altitude).
- Pushback clearance was requested via voice. During the push, the engines were started (usually just one engine, the other was started once on the parallel). After push, the parking brake was set and after start flows were completed. SOP at all airlines occurred once the parking brake was released; both pilots had 'eyes up' during the ramp taxi. When asked if CPDLC would integrate into the ramp taxi environment (example used was receiving an amended taxi clearance) all pilots said No—the ramp environment is too busy, too unpredictable, wing clearances can be minimal, and constant visual vigilance is required.
- Taxi clearance was requested at or near the movement line (if not before). Once underway, both pilots had heads up until the aircraft departed the apron area and was established on a parallel or taxi section with minimal exit and entry points. The other engine was started and after start flows were accomplished. One airline performed the departure briefing at this point, while the other airline briefed at the gate.
- When asked if CPDLC procedures for departure should be briefed, one airline said no and the other airline said that a short briefing might be useful if CPDLC was new to the airline or if one of the pilots had minimal experience with CPDLC. Contents of what the briefing should contain were not offered.
- When discussing the use of CPDLC during taxi (up to the runway hold short), the responses were varied and depended entirely on the circumstances. In general, both airlines felt that the taxi environment was too dynamic and required too much visual attention. When asked if it might be practical to set the parking brake to respond to a clearance, both airlines said No, but then clarified their response by saying that it might be possible, if equipped with two tillers, to have one pilot read and respond to the clearance, transfer taxi control to opposite tiller and have the other pilot verify. But, both airlines felt that this was not an ideal procedure. One pilot said that, depending on when the clearance was received, it would be acceptable for the pilot monitoring to read and respond and then have the other pilot (pilot flying) verify when able. The general consensus was that the taxi environment, with the current CPDLC technology was not appropriate. However, given newer technology (e.g., near-to-eye, airport moving map displays with taxi clearance overlays, or HUDS with taxi information) and quick response keys on the yoke, it might be possible to implement CPDLC in the taxi environment without any decrease in safety margins.

- All pilots said that CPDLC should be inhibited for the takeoff roll (at least the chime) until a safe altitude was reached. When queried about a specific altitude, all pilots agreed that it should be inhibited at least through aircraft configuration cleanup and once established on initial heading. All pilots said that initial climb is very busy with checklists, configuration, initial establishment, and if in VMC—other traffic. All pilots said they would be uncomfortable with CPDLC in the initial climb phase, especially in VMC conditions.
- Responders unanimously agreed that CPDLC was usable and beneficial in positive control airspace.
- In the approach phase, all pilots said that visual attention to the approach—from intercept down to the MAP required eyes forward. This phase of flight was too dynamic, especially if hand flying the aircraft. CPDLC was seen as a visual distraction, especially inside the marker when pilot flying and pilot monitoring needed to be constantly scanning the PFD and NAV displays looking for the runway environment, etc.

2.8.4.2. Miami Center (ZMA) and Miami TRACON Observations

A site visit was made to the Miami Center (ZMA) and to Miami TRACON to observe the ground side for controller procedures and get the ground perspective of controller workload as it relates to mixed equipage and mixed procedures. Figure 2-24 is part of the High Altitude Enroute chart for the Northeast sectors of Miami Center (ZMA). The eastern ZMA sector boundary is highlighted with the yellow line. The tailored arrival (TA) begins at SUMRS intersection on the ZMA boundary, passes through ZMA and enters Miami TRACON airspace Northeast of HILEY intersection. The TA route generally follows the A699 high altitude route. The TA route is modified from A699 to fly further West bound away from the North-South traffic along the coast of Florida. This is to minimize the conflict of the TA aircraft with the North-South arrival and departure traffic from South Florida area.

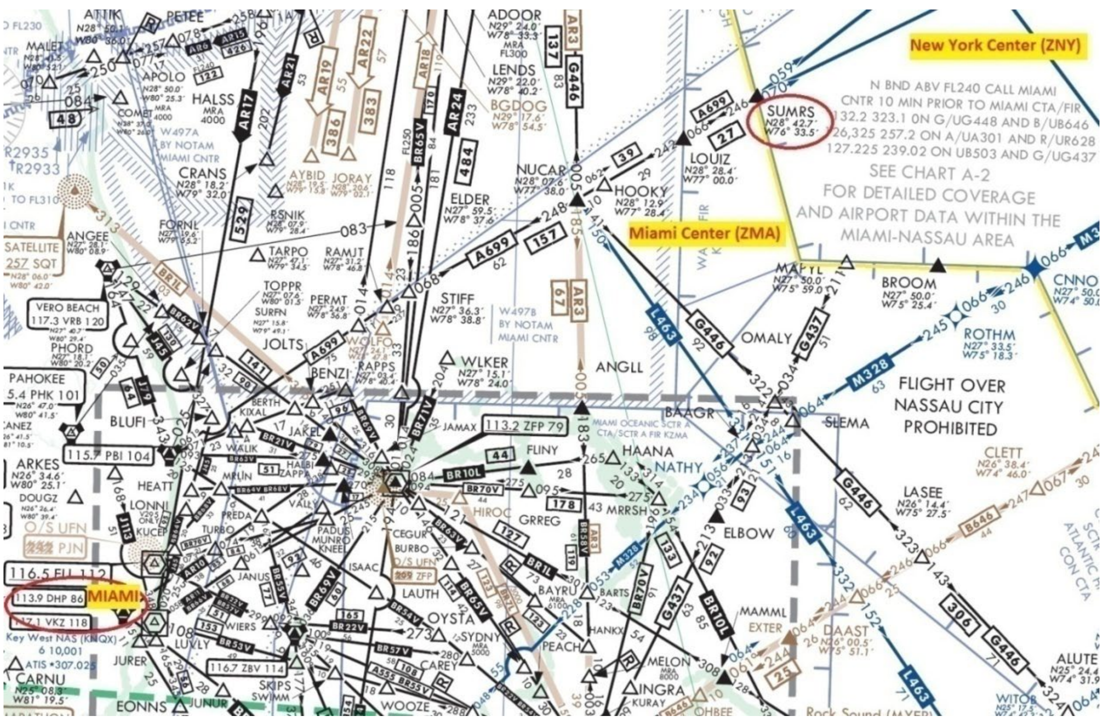

Figure 2-24. Miami Center Eastern Sector

2.8.4.3. Miami TRACON

Control and separation at TRACON is all performed manually. TRACON has limited the number of TA aircraft it can control at one time to one because of the added workload required by a single TA aircraft. Controlling the TA aircraft is not the issue, rather it is the other aircraft the controller must "get out of the way" and keep separation from the TA aircraft, because the controller does not have direct control over the TA aircraft. If the controller issues a heading or speed instruction, then the TA is ended and the remainder of the approach is performed using conventional vectors and altitude clearances.

The TA Arrival is not a published approach; as a result, the crew must request the TA prior to entering ZMA (Miami Center) airspace. The TA route inside TRACON airspace begins northeast of the HILEY waypoint in the STAR. The TA route is a modification of this STAR that was agreed upon by Boeing, MIA TRACON and several participating airlines. The TA arrival (called FLORIDA 8 for runway 8 and FLORIDA 9 for runway 9) is a modification of the HILEY STAR with numerous “AT OR ABOVE” altitude crossing restrictions. Both Boeing and the participating airlines consider TA procedure to be proprietary and will not divulge the details of the approach.

- All separation is performed using the radar screen and a few software tools.
- All aircraft within the controller's assigned sectors must be continuously scanned to "manually" keep the required separation between aircraft using only documented procedures, judgment, experience, and skill. No software tools provide the controller with heading or altitude recommendations to assist separation.

2.8.4.4. Summary of key procedural issues

Mixed procedures create high controller workload, because:

- The controller must keep the TA aircraft from overrunning slower traffic, creating high separation workload demands.
- Extra vigilance is required to monitor TA aircraft to ensure all the altitude restrictions will be made and that aircraft will turn at the required waypoints. The controllers still do not have the confidence that the TA aircraft will actually follow the flight path.
- Mixing a TA aircraft with the conventional vector controlling/separation created additional workload. The controllers have to judge 10 minutes ahead of the TA aircraft to avoid conflicts between the TA aircraft and all other aircraft, with the constraint that the controller cannot control the TA aircraft. The result is over compensation to keep separation.
- Forecasting the position of each conflicting aircraft while continuously scanning all other aircraft means the high cognitive workload projects 10 minutes into the future. Experience and skill are required to identify conflicts sufficiently far enough in advance.

2.9. Human Factors Issues with CPDLC

CPDLC differs in some important characteristics from air/ground voice communication and will therefore significantly change aspects of the flight deck tasks that affect the mental demands required to carry out tasks. This section provides an overview of those characteristics of CPDLC that have an impact on the flight crew task from a human factors approach.

Two classes of changes are identified: CPDLC can either make flight crew tasks easier (these changes are referred to as human factors capabilities or benefits) or it can make the flight crew tasks more demanding (these changes are referred to as human factors limitations or issues). For all identified human factors issues, recommendations are made for preventing or substantially reducing unwanted effects on CPDLC tasks. The recommendations refer to the CPDLC system and HMI design as well as operational procedures and training.

In NextGen, CPDLC communication is expected to replace or supplement voice communication to modify and communicate route trajectories. Researchers have investigated the effects of CPDLC on controller performance (e.g., 44; 57; 29). Some of the human factors challenges that have been identified include longer transaction times, difficulties in reviewing CPDLC communications, loss of “party-line” information that are available for situation awareness when pilots share a common radio frequency, and potential “head-down” time required for text-based data system.

The authors of [78] examined the human factors aspects of FMS usage strategies of commercial airline crews flying a Boeing 747-400 full-motion simulator in a terminal area flight segment. Results indicate that FMS-guided flight in the terminal area creates significantly more head-down time for individual crewmembers’ and increases levels of self-reported workload compared to conventional navigational means. The head-down aspect of this result can be extrapolated as an analogy for possible CPDLC effects, since CPDLC will also use the CDU (control display unit).

Reference [80] lists the following generic human factors categories that play a critical role in a majority of NextGen concepts:

- Attention allocation
- Decision-making and mental modeling
- Communication
- Memory
- Workload
- Interaction with automation, decision support tools, and displays
- Potential errors and recovery from human errors or system failures

Pilot response time, potential for pilot error, workload and situational awareness (SA) issues are all dependent on crew procedures [14, 25, 32, 33] message type, length and phraseology [69, 82, 94, 86], HMI design [27, 81, 92, 98, 107], clearance preview capability, FMS performance predictions and training [this report]. Problems with SA [5, 18, 44, 77, 63, 97, 100], mixed communication modes [72, 29], head-down time [81] and crew workload [91, 92, 98, 63] have been well documented in the literature [82, 98, 107].

Although [30] discuses CPDLC human factors issues with respect to ATC, these issues are analyzed in the following subsections as they apply to CPDLC on the flight deck.

2.9.1. Detection and Processing of Visual Information

Visual information (used in CPDLC exchanges) shows qualitatively different properties than auditory information (used in voice communication). These differences can have an impact on human information detection and processing. For instance, an advantage of visual information is that it is less transient than auditory information; thereby reducing working memory demands and the potential for error. On the other hand, visual information is more difficult to detect than auditory information. This means that (a) the detection latency for visual information tends to be longer, and (b) there is a higher risk of not detecting visual information (particularly, if the information is not presented within the operator's focus of attention). Moreover, if visual symbols are used to convey CPDLC related information (e.g. 'CPDLC enabled' status or 'log-on' status), there is a risk of misinterpretation.

The flight deck CPDLC HMI should support a timely detection of an incoming message. In order to do so, indications of incoming messages should be presented in the controller's focus of attention. Auditory alerts, in contrast, may not be recommendable. Flight crew should be trained on all visual symbols used for conveying CPDLC related information.

2.9.2. Competition for Visual Resources

The task of the flight crew, especially in the NextGen environment is already based on the detection, interpretation, and integration of large amounts of visually presented information. By shifting formerly auditory information (that is, voice) to the visual modality, there may be a risk of overloading the visual channel. Two different aspects have to be considered: First, perception and composition of CPDLC messages must not distract pilot's visual attention from any safety-critical displays. Second, if datalink information is presented on any other flight deck display, it must not obscure any safety-critical information.

To avoid diverting pilots' visual attention from the primary display, key information related to a CPDLC dialogue (e.g., the message notification and the status of a CPDLC dialogue) should be presented, preferably within the pilot's primary field of view.

CPDLC will compete for the pilot's visual channel. The authors of [50] found that pilots frequently missed altitude calls when the CPDLC message was uplinked during climbs or descents. When the pilot must monitor the aircraft's performance, navigation, flight guidance, or profile, CPDLC can directly compete with the concurrent visual monitoring task. With respect to CPDLC display modality, [61] reports that visual CPDLC display supports the best overall performance for general aviation pilots when the effectiveness of three different CPDLC interfaces involving auditory, visual, and redundant presentation of ATC information were evaluated in a single-pilot, general aviation simulation. Despite the requirement that visual display of datalink imposes for head-down activity, the permanence of the visual display allows pilots to allocate head-down time more flexibly and in a manner that is less disruptive of ongoing visual tasks than that needed to process (and take notes on) the auditory transmission of data.

2.9.3. Possibility of Flexible Task Allocation in the Flight Crew

With CPDLC, it is possible to modify task allocation within the flight crew in such a way that the PF and PNF (pilot not-flying) can support each other in carrying out CPDLC communication with ATC. The following issues need to be considered: (a) There is an increased need for intra-team communication to maintain clarity about which crew member is responsible for sending messages to ATC; (b) in case of reversion to voice (e.g., because of CPDLC failure or a dialogue timing out), the PNF will have to carry out the communication, regardless of who originally sent the CPDLC message.

Procedure design and training should include a clear division of tasks between the crew related to CPDLC communication. In particular, procedures need to describe which pilot role is responsible for sending which type of CPDLC messages. In the transition phase, it may be advisable to maintain the existing allocation of tasks between the PF and the PNF.

If the PF can send CPDLC messages, specific procedures for reversion to voice need to be designed and included in the training. The impact of the chosen task allocation (with respect to sending CPDLC messages) on other aspects of the crews role needs to be carefully considered.

2.9.4. Communication Errors

Errors in voice communication can be caused by miscomprehension of messages (failure to understand the message), working memory restrictions (failure to retain the message in memory), vulnerabilities of the read-back process (read-back and hear-back errors), and message confusion (erroneous receipt of messages). These errors are less likely in CPDLC, as the content of the dialogue is available in a more permanent written format. The more permanent nature of the dialogue makes it less prone to misperception or miscomprehension on the one hand and forgetting or misremembering on the other. A potential error relates to the situation in which the flight crew intends to send a certain message, but erroneously issues a different one (i.e., ‘slip of the tongue’). Although a similar error is possible with CPDLC (e.g., a wrong selection of a clearance for uplink), there is a higher chance that the controller will detect it if appropriate CPDLC procedure is followed.

2.10. Procedure Design Guidelines

2.10.1. Design objectives

Standard Operating Procedures for Flight Deck Crewmembers [35] outlines the key features of effective SOPs:

- The procedure should be appropriate to the situation.
- The procedure should be practical to use.
- Crewmembers should understand the reasons for the procedure.
- Pilot flying (PF) and pilot not flying (PNF) duties should be clearly delineated.
- Effective training should be conducted.
- The attitudes shown by instructors, check airmen, and managers should all reinforce the need for the procedure.

2.10.2. Compliance issues

Operational Authorization Process for Use of Data Link Communication System [36] provides guidance on the development of data link training:

- **CPDLC service academic training**. This training exclusively addresses knowledge requirements (rather than skills) and is usually related to achieving satisfactory knowledge of CPDLC service concepts, RCP types, systems, limitations, or procedures. The academic training on CPDLC services is generally accomplished using a combination of classroom methods (stand up instruction, slide/tapes, computer-based instruction (CBI), tutorial, etc.), flight manual information, bulletins, or self-study.

- **CPDLC service use training.** This training addresses all of the skills related to the operational use of CPDLC services, including knowledge and skills needed to receive information provided by CPDLC services and appropriately accept, reject, cancel, or defer a response to that information. In addition, this training includes the knowledge and skills needed to load, store, formulate, and request information from the CPDLC service.

2.10.3. Global Operational Data Link Document (GOLD)

The *Global Operational Data Link Document* [55] emphasizes the need to consider the fundamental differences between CPDLC and voice communications when developing or approving flight crew procedures involving the use of CPDLC.

For example, the document recommends that CPDLC flight crew procedures 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 as when using voice communication. Flight crew procedures should also ensure that each flight crew member (e.g. pilot flying and pilot monitoring - communicating) independently reviews each CPDLC uplink prior to responding and/or executing a clearance that it may contain and each CPDLC downlink message prior to transmission.

To minimize errors for CPDLC uplink messages, GOLD recommends that each flight crew member read the uplinked message independently (silently) before initiating a discussion about whether and how to act on the message. Reading a message independently is a key element to ensure that each flight crew member does not infer an inappropriate intent. Use of this method can provide a flight crew with an acceptable level of situational awareness for the intended operations.

3. Engineering Analysis

A major objective of this study was the development of recommendations for CPDLC operating procedures. Considering the mixed equipage expected to be in operation for CPDLC usage, the recommended procedure should be compatible with a variety of platforms. These include the capability for both manual and auto-loading CPDLC functionality. The procedure should also cover a broad range of air traffic control (ATC) uplink message (UM) elements with different message complexity and categorizations. Variation in pilot workload and tasks for different phases of flight also has the potential to influence CPDLC procedure. To address these goals and the broader objectives of this study, an engineering analysis was conducted to evaluate the limitations and capabilities of both legacy and new generation flight decks. As part of the data comm analysis, the NASA Aviation Safety Reporting System (ASRS) database was searched to identify reported the operational problems with CPDLC and FANS-1 communication technology. FCOMs were also surveyed to understand specific airline procedures. Surveys of airlines were also conducted to identify the implications of the datalink environment and specific airline crew procedures.

3.1. Method

In developing procedures for this study, we used a task analysis method that incorporated elements of verbal protocol analysis which encouraged participants to talk aloud while performing tasks. A task analysis provides a detailed account of the steps and user actions required to accomplish complex tasks. It can clarify a broad range of information to inform the design of a usable system including the development of standard operating procedure (SOP).

The experiment was not intended to be a formal, rigorous, and structured evaluation. Instead, the evaluation was an engineering analysis that used certified CPDLC software to observe limitations and capabilities and to develop initial crew procedures based on those limitations and capabilities. An engineering survey and analysis was done on the Boeing 777, Boeing 787, Boeing 744, and Boeing 733 data comm systems (B-777, B-787, B-747-400 and B-737-300 respectively) to evaluate the integration of the data comm systems with the on-board avionics (navigation and flight guidance systems) and selected ATC uplink messages (UMs). The intended outcome was to develop initial crew procedures that would work for any ATC uplink message on any of the platforms under study.

The Boeing 777 and Boeing 787 systems were used to evaluate data comm operation with messages that can be ‘auto-loaded’ into the flight management system (FMS). The Boeing 744 and the Boeing 733 systems were used to evaluate ‘manual loading’ of the message set. Twenty-five UM messages (clearances) were selected based on complexity and the ability to be auto-loaded into the B-777 and B-787. The UM message list contained a mix of altitude, speed, route and required time of arrival (RTA) clearances.

The methodology analyzed CPDLC procedures from message retrieval to automation set-up and execution. The task analysis method was used to help to understand the crew tasks required to configure the automation in order to comply with the ATC clearance when an ATC uplink was sent to the on-board CPDLC system. The methodology also allowed observations of CPDLC limitations and capabilities while observing and recording potential crew error. Human factors principles and engineering judgment were applied to the raw data to yield design guidelines for CPDLC crew procedures.

3.1.1. Participants

Two pilots participated in the evaluation. Both pilots were familiar with CPDLC communications. Details of participant backgrounds are presented in Table 3-1.

Table 3-1. Participant Background

Nationality	Crew Position	Current Aircraft Type(s)	Type Ratings	Total Hours	Datalink Familiarity
USA	PIC Part 121 Air Carrier and Production Test Pilot Eclipse Aviation	B-727 (1996), B-737 (2003), Eclipse Jet (2007)	Airline Transport Pilot Certificates (ATP); Certificated Flight Instructor – Instrument Airplane (CFI-IA)	12, 500	Yes
USA	PIC Part 121 Air Carrier and Graduate National Test Pilot School	B-777, B-737, B-727, GV-SP, Embraer 145RJ, CV-580, CV-600, CV-640	Airline Transport Pilot Certificates (ATP); Certificated Flight Instructor – Instrument Airplane (CFI-IA)	5,500	Yes

3.1.2. Task analysis Design

A within-subject (*repeated measures)* design was used for this evaluation. Both participants evaluated each Boeing platform datalink system with the same message set, uplinked in the same scenario order with assigned 'Pilot Flying' and 'Pilot Monitoring' roles. The known disadvantages of a within-subject design such as carryover effects, fatigue, and practice were not critical to this experiment since the main objective was to observe system behavior and develop procedures (versus observing scenarios under strict experimental control).

Both pilots flew the Boeing 733 in a "Manual Load" condition, followed by the Boeing 744 in a "Manual Load Condition." Both pilots then flew the Boeing 787 using the "Autoload capability of the FMS" and then flew the Boeing 777 using "Autoload." The scenario order is shown in Table 3-2. The independent variable for the experiment was the Boeing aircraft platform.

Table 3-2. Scenario Order

Participant	Scenario Order				
1	Training	B-733	B-744	B-787	B-777
2	Training	B-733	B-744	B-787	B-777

3.1.3. Data Collection

Subjective dependent measures comprising pilot comments (unsolicited and solicited through experimenter probe questions) and experimenter observations of task performance including potential errors were recorded. Participants analyzed the UMs for potential system problems and/or pilot error potential. Observations recorded during each flight included:

- How the crew built a shared understanding of the clearance
- The process the crew used to evaluate if they could comply with the clearance
- Capability of aircraft data comm system to successfully comply with a clearance
- How the crew setup the flight deck to comply with the clearance
- Automation techniques used (e.g., use of VNAV, LNAV, and level of automation)
- Use of crew crosschecks
- Verification of aircraft performance, guidance, and navigation
- Returning the CPDLC system to a default set-up in preparation for the next ATC uplink
- Any issues, quirks, 'gotchas' with system operation
- Potential areas for pilot error
- Crew procedures

The raw data was collected using scenario datasheets. Table 3-3 is an example of the collected data in Appendix H, Task Analysis Data. This example illustrates the data collected for UM20: CLIMB TO [*level*] for the B733. Data for each UM was also collected for B744, B777 and B787. Each UM was analyzed for issues associated with procedures, system design, SC214 message set design, and training. Also contained with each UM "raw data" is a table summarizing issues and a table providing recommendations.

Table 3-3. Example task analysis data entry for "CLIMB TO [16000]"

System	Steps	Key Pres	Task Time	Load FMS	Notes	Error Potential	Procedures
B733 UM20	1. CPDLC Chime 2. Select FMC Comm Page 3. Read Message 4. Dial "16000" in the MCP ALT window 5. Send WILCO 6. Select PROG or LEGS page	5	:20	No	This MCP ALT window is also the Altitude Alerting System (inhibited FLAPS ≥ 25 or G/S capture).	Using the MCP ALT selector, the pilot can select (overshoot) a lower altitude, say 8700 ft, and the AIRCRAFT can capture the lower altitude and level-off at 8700 instead of 9000 ft.	During climb out, ATC requires to stop climb at 16,000 ft. The CRZ ALT in the FMS CLB page is set to FL330 – the final cruise altitude. To stop climb (or descent), the current procedure is using the MCP ALT select knob to enter the level-off altitude

3.1.4. Evaluation Facility

The evaluation was conducted using a B-733, B-744, B-787, B-777 fixed-base engineering flight simulators at Honeywell's Phoenix facility. The engineering simulators had the following configurations and level of fidelity:

- Fixed base simulator
- No visuals
- Certified software for flight management system (FMS)
- Certified software for datacom systems
- Certified mode control panel with full functionality
- Certified autopilot/autothrottle/flight director/ mode control panel/FMS CDU
- Certified full LNAV and VNAV guidance capability
- Certified primary flight display (PFD), navigational display (ND), and Engine Indicating and Crew Alerting System (EICAS)
- Autobrakes
- Operable flight controls (yoke, flaps, gear, speed brakes)
- Simulated radios and global positioning systems
- Current NAV database
- Limited system functions for hydraulics, APU, electrical, environmental, and pneumatics
- Fuel flow and monitoring system
- Simulator ability to set initial conditions and position (altitude, speed, position), simulator pause, accelerate functions.
- AIR SIM simulator to simulate ground side ATC station for sending and receiving ATC messages.
- Full aural alerting for Master-Caution and CPDLC alerting.
- High-fidelity flight performance models (not certified performance packages)

- Aircraft models:
  - B-787 model: auto-load capability
  - B-777 model: auto-load capability
  - B-744 model: manual-load capability
  - B-733 model: manual-load capability

3.1.5. Equipment Limitations and Capabilities

Table 3-4 summarizes the main differences between platforms.

Table 3-4. Differences between platforms

FMS Differences
733 (Smiths-Thales FMS) • The Smiths FMS allows a down-path OFFSET to be inserted at a down-path waypoint and end at a down-path waypoint. 744, 777 and 787 (Honeywell FMS) • Can do OFFSETS from present position only. Cannot do down-path OFFSETS. • Honeywell FMS cannot accomplish RTAs in the climb and descent phases of flight. • The B-787 can generate FMS 'help' messages for FMS entries in the scratchpad that generate an error message. The 'help' messages provide corrective guidance to the crew. These 'help' messages are displayed within the ATC Message Window on the glass MCDU.
Display Differences
• The Boeing 787 provides a sidelink to 'pop up' a visual crew reminder for conditional clearances. As the aircraft approaches the point where the clearance becomes effective the visual reminder to execute the clearance 'pops up' in the center MFD CDU. • Boeing 787 has 'DIALABLE' messages. The 787 can send altitude, speed, and heading values to the appropriate MCP (mode control panel) window display as a commanded value (not loaded). When pilot dials window value to match the value sent to the MCP window, the value turns green, as does the value in the ATC Clearance text in the ATC Aux display. The Boeing 777, 733, and 744 do not have this feature (although it is expected that B-777 will reach commonality with the B-787)
CPDLC Control Differences
• The Boeing 733 and 744 display the CPDLC through the MCDU which is shared with other aircraft systems (e.g. FMS). CPDLC uses the MCDU keyboard for control. Center EICAS displays. ATC chime and Aural Warning Computer sounds chime. ATC response (WILCO, REJECT, STANDBY) is accomplished via the MCDU line select keys. • The Boeing 777 and 787 used dedicated controls and displays for CPDLC. There are dedicated displays for the operation and display of data comm and CPDLC. Brow shield buttons for WILCO, REJECT AND CANCEL. Boeing 777 uses free floating cursor with 'hot corners' and keyboard. Boeing 787 uses free floating and discrete cursor + keyboard. • Boeing 787 and 777 have 'loadable' message formats understood by the FMS (see Appendix G). Some degree of parameter validity and crosschecking with aircraft performance prior to triggering the LOAD prompt is accomplished by the FMS.

3.2. Evaluation Scenario

A Boeing flight test scenario was used. The scenario was a route originating from KBFI (Boeing Field/King County International Airport, Seattle, WA, USA) and flown round robin to KOAK (Metropolitan Oakland International Airport, Oakland, CA, USA) and back to KBFI. The total flight distance was approximately 1802 nautical miles. The long route distance was required to accommodate full testing of all the selected UMs without flight interruption.

3.2.1. CPDLC Message Selection

Table 3-5 is the list of selected UMs for the task analysis. Different groups within each column (category, loadable, dialable) are color-coded to aid readability. The colors used do not indicate prioritization or emphasis. The complete list of SC-214 Uplink Message Set is contained in Appendix F. The UMs were selected based on loadable capability, complexity, and relevance to trajectory-based operations (TBO). The selection of UMs was balanced to include typical UMs from altitude, speed and route categories.

Table 3-5. Selected Uplink Message Set for Task Analysis

UM	Message Element	Use Description	Category	Load-able	Dial-able
20	CLIMB TO [*level*]	Instruction that a climb to a specified level is to commence and once reached the specified level is to be maintained.	Altitude		Yes
27	CLIMB TO REACH [*level*] BY [*position*]	Instruction that a climb is to commence at a rate such that the specified level is reached at or before the specified position.	Altitude		Yes
47	CROSS [*position*] AT OR ABOVE [*level*]	Instruction that the specified position is to be crossed at or above the specified level.	Altitude	777, 787	Yes
49	CROSS [*position*] AT AND MAINTAIN [*level*]	Instruction that the specified position is to be crossed at the specified level and that level is to be maintained when reached.	Altitude	787	Yes
50	CROSS [*position*] BETWEEN [*level*] AND [*level*]	Instruction that the specified position is to be crossed at a level between the specified levels.	Altitude	787	Yes
56	CROSS [*position*] AT OR LESS THAN [*speed*]	Instruction that the specified position is to be crossed at a speed equal to or less than the specified speed and the specified speed or less is to be maintained until further advised.	Altitude	787	Yes
61	CROSS [*position*] AT AND MAINTAIN [*level*] AT [*speed*]	Instruction that the specified position is to be crossed at the specified level and speed, and the level and speed are to be maintained.	Altitude		Yes
290	DESCEND VIA [*procedure name*]	Instruction to descend via the specified procedure.	Altitude		
295	AT [position] CLIMB VIA [procedure name]	Instruction that when reaching the specified position to climb via the specified procedure.	Altitude		
106	MAINTAIN [speed]	Instruction that the specified speed is to be maintained.	Speed		Yes
108	MAINTAIN [*speed*] OR GREATER	Instruction that the specified speed or a greater speed is to be maintained.	Speed		Yes
109	MAINTAIN [*speed*] OR LESS	Instruction that the specified speed or a lesser speed is to be maintained.	Speed		Yes
116	RESUME NORMAL SPEED	Notification that the aircraft need no longer comply with the previously issued speed restriction.	Speed		
188	AFTER PASSING [*position*] MAINTAIN [*speed*]	Instruction that after passing the specified position the specified speed is to be maintained.	Speed		
310	AT [*level*] MAINTAIN [*speed*]	Instruction to maintain the specified speed upon reaching the specified level.	Speed		
64	OFFSET [specified distance] [direction] OF ROUTE	Instruction to fly a parallel track to the cleared route at a displacement of the specified distance in the specified direction.	Route	777, 787	

UM	Message Element	Use Description	Category	Load-able	Dial-able
65	AT [position] OFFSET [specified distance] [direction] OF ROUTE	Instruction to fly a parallel track to the cleared route at a displacement of the specified distance in the specified direction and commencing at the specified position.	Route	787	
74	PROCEED DIRECT TO [*position*]	Instruction to proceed directly from present position to the specified position.	Route	777, 787	
77	AT [*position*] PROCEED DIRECT TO [*position*]	Instruction to proceed, at the specified position, directly to the next specified position.	Route	777, 787	
84	AT [position] CLEARED [procedure name]	Instruction to proceed from the specified position via the specified procedure.	Route	787	
91	HOLD AT [*position*] MAINTAIN [*level*] INBOUND TRACK [*degrees*] [*direction*] TURNS [*leg type*]	Instruction to enter a holding pattern with the specified characteristics at the specified position and level.	Route	777, 787	
252	CROSS [position] AT [RTAtimesec]	Instruction that the specified position is to be crossed at the specified time.	Route	777, 787	
258	CROSS [*position*] AT OR AFTER [*RTAtimsec*] AT [*level*]	Instruction that the specified position is to be crossed at or after the specified time and at the specified level.	Route	787	Yes
268	AT [position] CLEARED [route clearance enhanced]	Instruction to proceed from the specified position via the specified route.	Route	777, 787	
339	AT [position] CLEARED TO [position] VIA [route clearance enhanced]	Instruction to proceed from the first specified position to the second specified position via the specified route	Route		

3.3. Evaluation Procedure

The evaluation sequence was as follows:

1. **Briefing.** Pilots were given a verbal briefing of the evaluation objectives and the operation of the datalink system prior to the evaluation. This briefing consisted of an explanation of the datalink display, description of the evaluation platforms, evaluation objectives, and description of the evaluation scenario route. Pilots were assigned and briefed on their roles for Pilot Flying (PF) and Pilot Monitoring (PM).
2. **Training**. Each pilot was trained on the data comm system for each platform (B-787, B-777, B-744, and B-733). For each flight deck data comm system, the training included how to initiate each response type (WILCO, REJECT, STANDBY), how to cancel the message, and how to set-up the system for the next ATC uplink message.
   2.1. **Flight Number 0**: Each pilot received three trials for each message category (altitude, speed, route, and RTA). The training included how to retrieve, view, load clearance into the FMS, set up automation, and respond to ATC.
3. **Flight Number 1**: Pilots flew the Boeing flight test scenario. The two participant pilots were each assigned to either PF or PM roles. The key instruction was that the PF would be PIC, fly the aircraft, and handle the automation set-up. The PM would handle the CPDLC communications and provide standard call-outs. The twenty-five UMs were uplinked in a specified order during the scenario. The purpose of this flight was to observe the data comm system operation and record the pilot steps required to view, retrieve, evaluate, set-up automation, and respond to ATC.
4. **Flight Number 2**: This flight was flown identically to Flight Number 1. The purpose of the flight was to support CPDLC procedure development.
5. **Flight Number 3**: This flight was flown identically to Flight Numbers 1 and 2. The purpose of the flight was to verify procedures developed in Flight Number 2. The procedures developed in the Flight Numbers 2 were tested again in the Flight Numbers 3.

3.3.1. Operational Descriptions and Definitions

This section provides operational definitions of terminology related to the experimental design.

Task. A task is defined as the actions a crew performs responding to an ATC clearance message. Examples of crew actions to a UM include: retrieving the clearance, evaluating the clearance, setting up the FMS, verifying the FMS, executing the FMS modified flight plan, verifying performance, and responding to ATC. For each trial flown with each UM, pilot task sequences in 'handling' the UM and setting up the flight deck are observed.

Task Time (where applicable). Task time is the time the crew required to respond to an uplink message clearance. The task starts when crew is alerted and ends when the crew acts on the clearance and responds to ATC with a downlink message. Task Time provided a measurable metric and allowed us to observe the full crew procedure for responding to a UM.

Task Analysis. The task analysis included the sequence of the "sub-tasks" required to receive, evaluate, and respond to the ATC clearance. Observations and comments on the procedures and techniques were recorded for each UM and for each aircraft. Structured flight scenarios, with a common set of messages, combined with unstructured debate produced rich observations and data that could be used in the development of CPDLC crew procedures.

Complex message: Complexity of CPDLC messages was defined by the number of CPDLC message elements contained in a single ATC message. Although individual message elements, for example route, speed, and altitude, can be considered simple in terms of the response actions required and the crew analysis of aircraft performance. Their combination into a single message results in extra information processing requirements; therefore, an essential differentiator of a complex message is the interdependencies between the individual message elements, the complexity of evaluating the clearance and the complexity of loading the clearance into the FMS and Autoflight systems. Message complexity is multi-dimensional and should be defined not only by the individual message elements, but by message type (e.g. EXPECT and CONDITIONAL), complexity of the loading operation, and the complexity of evaluating the probability of a successful execution. All these components of message complexity will impact cognitive crew workload depending on the HMI interface and the sophistication of the decision aids on the flight deck.

Loadable. Loadable UMs are the uplink messages containing ATC clearance information that can be automatically loaded by the Datalink avionics into the FMS. The B777 and B787 are the aircraft in our study that can use loadable UMs. The loadability of the UMs used in the analysis is identified in Table 3-5. Most of the route clearances are loadable. A loadable UM is a clearance containing navigation or guidance information that does not have to be manually loaded into the FMS. A technical definition of "Loadable UM" was obtained from a discussion with Honeywell avionics engineers.

Dialable. A dialable UM allows the crew to see the clearance altitude, heading and/or speed displayed on the MCP when the clearance is acknowledged by a reply DM, such as DM0: WILCO or DM3: ROGER. Another feature of a dialable UM is feedback when the pilot dials.

If an uplink message contains altitude, speed or heading data intended for the MCP as an autopilot controlling parameter, the CMF first performs validity checks on the data. If the data pass these checks, the communication management function (CMF) forwards the data to the MCP when accepted by the crew, except for conditional clearances, where it is only forwarded when the condition is met and the uplink has been accepted. The data appears in a standby window of the MCP, which is transferable to the active MCP windows. The pilot transfers the altitude, heading or speed value "manually" by dialing it in, so the avionics does not load values in the MCP that can be used by the guidance system -> they are only display values for the pilot to reference.

Figure 3-1 illustrates the sequence of steps when “UM20: CLIMB TO [FL350]” is received by the CPDLC avionics Communication Management Function (CMF). The 35000 altitude value is displayed in the lower half of the MCP ALT window after the uplink has been ACCEPT’ed. The displayed altitude value is a visual aid to help the pilot dial the correct altitude in the MPC ATL window.

The CMF also uses the altitude value to provide another pilot visual aid using dial feedback. When the pilot dials the altitude in the MCP ALT window to match the uplinked altitude value, the alphanumeric altitude value contained in the UM displayed in the AUX panel and the on the MFD if the UM is displayed from the ATC page, the text turns from white to green. This feature is called “dial-able” and the UM is a “dial-able” UM.

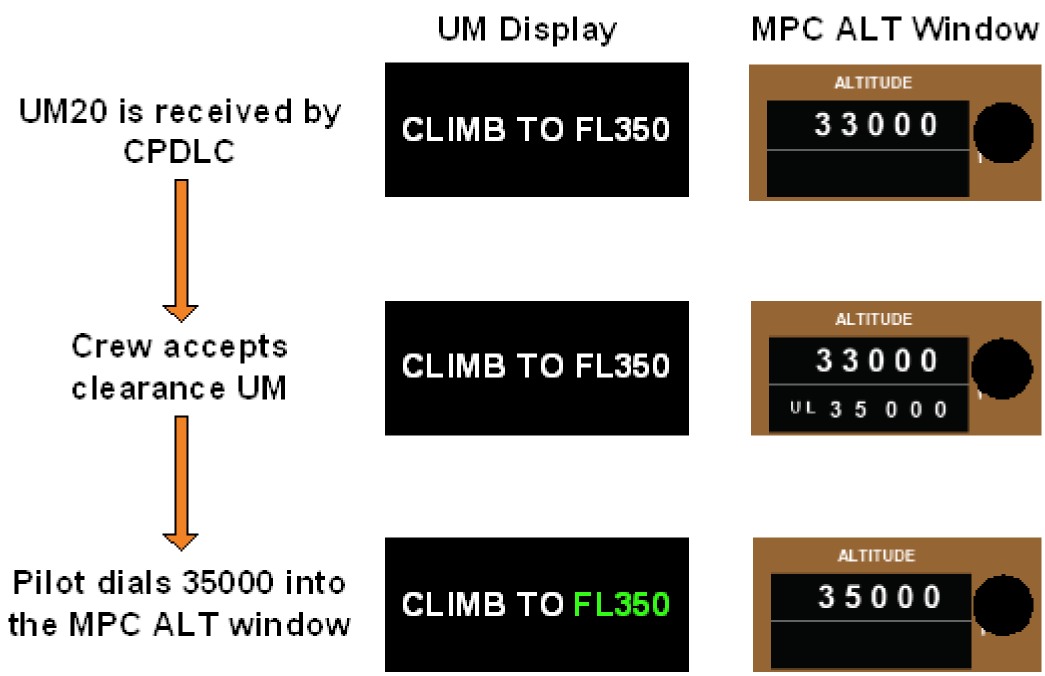

Figure 3-1 Dialable Steps

3.4. Results

3.4.1. ASRS Lessons Learned

Table 4.1 is a summary of conclusions compiled from a search of the NASA Aviation Safety Reporting System (ASRS) database. This data search identified the operational problems with CPDLC and FANS-1 communication technology. Detailed listings of the ASRS reports (with ACN numbers) and comments are presented by category in Appendix E. Table 3-6 summarizes the underlying problems found in 87 ASRS reports; they are grouped into 6 categories. The problems were formatted as “lessons learned” and informed the procedure development process.

Table 3-6 Lessons Learned

Category	Lessons learned
Misread Clearances: Problems associated with reading or understanding datalink clearances	Conditional clearances are easy to miss. Although conditional clearances may also be misunderstood or forgotten in voice communications, read back allows the controller to emphasize the conditional restriction, making it less likely that an error will occur.
	Crews ask for and are eager to receive a climb clearance. They are usually not expecting a conditional climb clearance and are vulnerable to misreading a clearance.

Category	Lessons learned
	Too much and poorly formatted information in a clearance can cause the pilot to overlook an important feature of the clearance.
	Format the conditional clearance to be obvious to the pilot.
	Small font formats make the short word ‘**AT**’ hard to notice.
	When ATC asks a question or gives an ‘EXPECT’ message, the response displayed to the pilot should not be ACCEPT or REJECT.
	Highlight changes to flight plans to make them easy to see between the old and new flight plans.
	Multi-page messages are difficult to read and easy to miss.
ATC Uplink Problems: Problems with ATC CPDLC equipment, procedures or clearances	Use of CPDLC requires complex equipment and protocol and seems more susceptible to problems than voice.
	Outages and ground equipment problems that crew don’t know about can cause major problems. Status of the ground signal and equipment should be continuously monitored by airborne equipment.
	Ground equipment or controllers may send messages to wrong aircraft; messages are too easy to read and acknowledge without checking.
	Crew should check the aircraft identification on the UM to ensure the message is sent to the right aircraft.
Procedure Problems: Problems with the aircraft using the CPDLC	Procedures developed need to be compatible internationally to minimize potential issues.
	Testing CPDLC in a taxiing environment increases the pilot workload, generally not accepted by pilots. Pre-taxi assigned route is good, but tends to change due to many factors. This change causes problems.
	Inherent delay in receiving CPDLC reply
	Two UMs sent in close sequence could confuse the crew as to whether a UM completely or partially overrides previous UM clearances.
Equipment Problems: Problems with the aircraft using the datalink	There could be inherent delay in receiving CPDLC reply.
Emergencies: Using the datalink in an emergency situation	
	Pilot to enter a max delay time the crew can wait for an ATC response for weather deviation
	Voice communication used when CPDLC is not immediately effective
	CPDLC technology should not contribute to an emergency

Category	Lessons learned
Situations in which CPDLC would have Helped: Problems crews had and commented that the datalink would have averted the problem	These are various pilot and controller comments about how CPDLC would have reduced or eliminated the reported problem. See Appendix E for comments.

3.4.2. Operational surveys

End user surveys form an important component of the Honeywell design process. Meetings (teleconferencing, in-person, etc.) with airlines provided a way for the research team to refine the task analysis by incorporating more accurate information about the implications of the datalink environment and specific airline crew procedures. The surveys and accompanying discussions also provided an opportunity to understand pilot preferences, company policies, and other operational constraints. A structured questionnaire was used to collect airline responses. Both major and regional carriers were interviewed to get a wider perspective on crew tasks and communication procedures for all phases of flight. The results of the operational surveys are presented in Table 3-7**.**

Table 3-7. Results of Structured survey of Airline #1

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
General	Your position in the company, flight check airman or flight standards work?	Pilot # 2 FO) 3000 hours in type (170) Pilot # 3 (FO) 2400 hours in types. Both have check airman experience. Crews hub out of Chicago O'Hare.	Pilot # 1. Airbus Captain A320 flight Check Airman for USAIR
	Length of employment and hours	5 years for both	25 years
	Equipment and routes	Domestic	Domestic and Canada
	Is your airline considering CPDLC all phases?	Not considering CPDLC at this time. Airplanes are ACARS equipped. ACARS is used to get PDC, digital ATIS, AOC, and send weight and balance numbers.	CPDLC on A330 (international routes) only. ACARS capable of receiving route clearances from company and PDC clearances where available at airport.
	Do you have procedures for other than enroute?	Use of ACARS is a gate activity. When aircraft is under movement on the ramp. Both eyes are up. Afterstart flows are allowed but usually done with brake set after engine start. Once under movement SOP is to be heads up.	
	Does your aircraft have dual tillers?	Dual MCDUS and single tiller	Dual tillers on Airbus

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
	Read clearance independently?	Get PDC and ATIS prior to pushback. Send weight and balance through ACARS. Power up, do preflight check, then ACARS work. Weight and balance goes out prior to pushback. FO does walk around, FO ACARS, FO does data entry with flight plan. When the other pilot comes up to the cockpit they both must verify the FMS entries against the PDC. This is done independently and then confirmed with each other.	Only things you can do while taxiing is SOP as defined by your airline. Captain is always taxiing, no transfer of control on the ground and no exceptions. FO allowed to talk on radio. If change in taxi clearance while taxiing, then FO talks on the radio and confirms clearance with the Captain. Operational necessity determines when and how clearances are read and confirmed.
	How do you check data entry (FMS, MCP, other)?	Enroute, PF does all inputs into MCP if AP on. PM will do MCP or FMS inputs if PF is hand flying. Their philosophy is to always have the PF do any input that controls the aircraft. PIC or PF must always be in the loop and in control. For any input (FMS or MCP) they both must confirm and confirm indications on displays. Prior to input, both pilots must confirm clearance.	In taxi with data entry PM will ask if captain wants to confirm. If so, the captain will confirm when able.
	What procedures do you currently use to verify clearances with the other crewmember?	See above	See above
	What procedures do you use to verify proper data entry for clearances (e.g. route, speed, altitude, etc.)?	For Enroute segment. Other phases may or will require different procedures. If CPDLC, both pilots should read clearance independently. If aircraft is being manually flown (rare). Positive transfer of control should take place. Both verbally confirm clearance. Both verify confirm data entry. This was for enroute.	In flight if on autopilot, the pilot flying enters data. Pilot not flying confirms the data entry. If PF is busy, then PF confirms the data entry when able. If a pilot leaves the cockpit, remaining pilot enters data and flies and when other pilot comes back they both confirm the clearance and data entry. Airline and pilots assume a level of competence in other crewmember.
Gate	What procedure does airline use to obtain, enter and verify ATC route clearance?	See above	Where available the standard method is to receive the clearance via PDC. The clearance is then printed and clipped to yoke or put on console. The PDC is checked against the datalinked clearance from the company that is sent via ACARS. The pilot must call ground control and confirm that the clearance was received and confirm the squawk. A full read

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
			back of the route is not required.
	How is ACARS used to get the clearance?	See above	Would request clearance from company datalink. Clearance datalinked to ACARS and then from ACARS would autoload directly into FMS. Would have to compare ACARS datalink clearance with paper.
	When is ATC route clearance obtained (before cockpit setup)?	When parked at the gate. ACARS gets the PDC. PDC is printed out. ACARS work is done after safety checks and power up. Both pilots said it is rare, but possible to get a change in taxi clearance enroute to the runway. More common to get an updated ATIS	When parked at the gate
	Who gets the ATC route clearance and ATIS and enters data into the FMS?	See above.	Either person could get the clearance at the gate. But company required both pilots view the clearance and compare entry into FMS.
	Does the captain delegate getting clearance and setting up the FMS to the FO?	No, both pilots have to confirm.	No both pilots have to confirm.
	How does your airline know if you are ready for pushback?	Ramp control at larger airports, but ground control at smaller airports.	Ramp control at larger airports, but ground control at smaller airports.
Crew Briefing - Taxi	Importance of a crew briefing, CPDLC prior to departure. What items should be covered for taxi and departure?	Briefing at the gate before pushback. A comment was made that a briefing for CPDLC should be done when CPDLC is new and SOPs are being reinforced. It may be modified later and shortened to "standard procedure' once experience is gained.	Crew briefing for departure that was done at gate: all the departure particulars, how to handle CRM and emergency procedures. Take off brief (head, initial altitude, first fix, then captain's preference). Takeoff brief done prior to runway after second engine started. Usually done on a parallel taxiway.
	When do you do the departure briefing?	Once out of ramp area and heading towards runway. Will usually wait until they are on a parallel or some other section that doesn't require all their attention.	Once out of ramp area and heading towards runway. Will usually wait until they are on a parallel or some other section that doesn't require all their attention.

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
Ramp Taxi	Ramp and CPDLC?	Most often they will call for taxi clearance after pushback. But brakes are set and aircraft is not under movement. The clearance is typed into the MCDU scratchpad as a reminder. Both crews verify clearance and then verify against 10-9 chart. No heads down on ramp while aircraft is moving. If something needs attention and operational necessity demands it, then aircraft must be stopped if possible and parking brake set.	CPDLC wouldn't work. Too congested. Too dynamic. Too much movement. Cannot stop without creating chaos. Too many opportunities for hear back error.
	What are your procedures for ramp operations?	On ramp just after start flows. After start flows are done but not much else.	Heads up but there are afterstart flows. Pilot not flying very busy.
	Does captain delegate taxiing to FO?	No - never	No - never
	Is ACARS used for ramp operations?	Just at gate	Used at the gate for PDC and company clearances.
	Allow any checklist, FMS during taxi?	After start flow is done on the ramp after engine start, but parking brake is set and aircraft not moving. Both are heads up for ramp. Pilots stated that one advantage of voice is SA on the ramp. They like to know who is pushing back (could be an A380 that may get close or have implications). Another example was a B777 that got lost on a foggy night in ORD. The crew stopped the aircraft but nose was poking into the runway. The aircraft in position and hold decided not to take the takeoff clearance until the B777 found itself. Would have caused an accident. SA advantage with voice. However, pilots said that with improved AMM displays with ADSB-IN that SA would be as good	Yes - non taxiing pilot (FO) can talk to company, do their flows, talk to PAX while aircraft is under movement

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
Taxi to Runway	How would you handle CPDLC crossing intersections or runways? What if FO must call company or people in back and you get a CPDLC message? Transfer of control issues: FO putting in new clearance FMS, you are taxiing aircraft, how would CPDLC be handled? How is it handled today with voice?	With dual tillers could transfer control. Stopping most likely will not be operationally feasible. Too many instances were cited where captain taxiing could not go "head away" (from the taxing task) for even one second to read the clearance on the MCDU. Cases of skidding, ice on taxiway, busy environment, dicey aircraft control with high winds. CPDLC could work with heads up technology (HUD and digitized voice). Or in a dual-tiller situation where transfer of control could take place. They said CPDLC might be acceptable as long as they had the option of going to voice when operations prevented them from going heads down.	Some circumstances when airplane gate is literally yards from runway. Crew must be very busy to get everything done because operationally necessity required it.
	Frequency and type of clearances during taxi (if extended may go to voice if short and not critical then could use CPDLC)?	Not common but would get changes to taxi clearance especially O'Hare or clearance like 'see that 777? Follow him.'	Not common but would get changes to taxi clearance especially O'Hare or clearance like 'see that 777? Follow him.'
	Allow any checklist, FMS during taxi?	Not while aircraft is moving.	Did allow when aircraft was moving
Hold Short	Voice or CPDLC? (FO out of loop for other duties (cabin, company, etc.)	If FO is involved with other tasks (or Captain) and a clearance comes in, then other pilot must be briefed on the clearance and any data entry when his/her attention returns.	
Hold in Position	Voice or CPDLC? (FO out of loop for other duties (cabin, company, etc.)	Voice only. Time criticality of emergency events precludes the use of CPDLC. E.g., thought position and hold but then cleared for immediate takeoff.	Voice only. Time criticality of emergency events precludes the use of CPDLC. E.g. thought position and hold but then cleared for immediate takeoff.
Takeoff prior to V1	Should we inhibit CPDLC chime and message, just chime? To what altitude?	Inhibit chime. Takeoff should be Voice only.	Inhibit chime. Takeoff should be Voice only
Post V1 to cleanup altitude	Voice or CPDLC? If CPDLC procedures for use?	Voice only.	Voice only
Initial Climb to 800	Crew procedures in terminal environment with VFR traffic, VMC and CPDLC.	Voice only. Too busy, very dynamic, VMC traffic, close to ground. Eyes need to be forward at all times.	Voice only. Too dynamic of a phase.

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
1000 ft. Aircraft Configuration and climb checklist	Crew procedures in terminal environment with VFR traffic, VMC and CPDLC.	Same situation. In their aircraft there is a very large after takeoff flow. Very busy with profile, configuration, checklists. Unless it is for separation or other operationally needed com they would like to see very little or no com during initial climb. Not altitude limit was specified but they suggested sterile environment till 10,000 unless it was time critical.	Does not see it working for tower operations. High threat environment. Can't get a hold of you fast enough using CPDLC.
During initial turn	Crew procedures in terminal environment with VFR traffic, VMC and CPDLC.	Same	Same
Climb 10,000 to TOC	Intermediate Level Off - receiving CPDLC. Also, VMC with traffic.	CPDLC OK above 18000. In VMC both heads up and out below positive control airspace. The pilots expanded on this saying that both reading and verifying below positive control airspace was OK but both pilots need to do it one at a time. Also, procedures should reflect whether the aircraft is being manually flown or not. Whether one can divert attention away from a manual flying task depends on the circumstances but there may be cases where it is not good SOP such as intercepts, altitude level offs, or other capture situations	CPDLC OK above 18000.
Enroute	Flying pilot flies. If comm guy doing FMS at request of pilot what is priority if CPLC comes in.	During enroute segments would like the PM to read clearance out loud with PF flying. Both would confirm data entry. PF would confirm when able if busy with other chores. Only phase where it would be OK for pilots to both independently read and then mutually confirm. Cannot see using CPDLC below positive control airspace.	During enroute segments would like the PM to read clearance out loud with PF flying. Both would confirm data entry. PF would confirm when able if busy with other chores. Only phase where it would be OK for pilots to both independently read and then mutually confirm. Cannot see using CPDLC below positive control airspace.
	Both independently read.	During enroute segments would like the PM to read clearance out loud with PF flying. Both would confirm data entry. PF would confirm when able if busy with other chores. Only phase where it would be OK for pilots to both independently read and then mutually confirm. Cannot see using CPDLC below positive control airspace.	During enroute segments would like the PM to read clearance out loud with PF flying. Both would confirm data entry. PF would confirm when able if busy with other chores. Only phase where it would be OK for pilots to both independently read and then mutually confirm. Cannot see using CPDLC below positive control airspace.

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
TOD to 18,000	Both independently read.	During enroute segments would like the PM to read clearance out loud with PF flying. Both would confirm data entry. PF would confirm when able if busy with other chores. Only phase where it would be OK for pilots to both independently read and then mutually confirm. Cannot see using CPDLC below positive control airspace.	During enroute segments would like the PM to read clearance out loud with PF flying. Both would confirm data entry. PF would confirm when able if busy with other chores. Only phase where it would be OK for pilots to both independently read and then mutually confirm. Cannot see using CPDLC below positive control airspace.
Terminal Area - Initial Approach (configuration)	VMC and traffic.	Voice only in this environment. . But if hand flying and watching LOC. They felt that cases where weather is bad, terrain is high, manually flying, that CPDLC is a distraction. Then it is operational necessity that both pilots need to be watching. Too dynamic. Would like to have digital voice. On a vector to intercept LOC but no clearance to intercept. Shouldn't fly through but don't have clearance. Channel too busy to break in. Autoload for runway change if it is late is good. In some cases autoload for late runway changes.	Voice only in this environment. Consider it to be a 'high threat' environment.
IAF to FAF	Voice or CPDLC?	Not in the approach area. Why did they give us a headset with a trigger on yoke? So you wouldn't have to look away.	Not in the approach area. Why did they give us a headset with a trigger on yoke? So you wouldn't have to look away.
Inside FAF to Minimums	Voice or CPDLC. Monitored approach?	Voice only. Eyes to be monitoring approach. Too dynamic for changes.	Voice only. Eyes to be monitoring approach. Too dynamic for changes.
Rollout	Voice or CPDLC?	Voice only. Time criticality. Too dynamic	Voice only. Time criticality. Too dynamic.
Missed approach initial	Voice or CPDLC?	Time criticality. Very dynamic. Crew busy with higher priority tasks. Cannot see surface or approach (approach break off) so any time critical. On ground too much congestion, too time critical (stop hold position)	Time criticality. Very dynamic. Crew busy with higher priority tasks. Cannot see surface or approach (approach break off) so any time critical. On ground too much congestion, too time critical (stop hold position)
General Events			
Hand flying versus AP procedures for CPDLC	Voice or CPDLC?	May need to modify CPDLC procedures depending on weather aircraft is on autopilot or is being hand flown.	
Negotiation	Voice or CPDLC? Phase of flight dependent.	Can see using CPDLC to negotiate a clearance enroute but not below positive control airspace	Can see using CPDLC to negotiate a clearance enroute but not below positive control airspace

Flight Phase	Questions-Conditions	Airline #1 Response	Airline #2 Response
Pilot leaves cockpit	Procedure for briefing other crewmember?	When the pilot returns, must be briefed on the clearance. Both pilots verify all data entry.	
Standard Data Comm setup after receiving and responding to a message.	How do you currently set up your radios and monitoring?	Both pilots keep current ATC on COMM 1 with previous in standby. Company Frequency on COMM 2. No change in radio configuration without discussion.	
Conditional Clearances	What procedures do you use for conditional clearances?	For conditional clearances, they will 'draw' a symbol on the ND. And they will put a reminder in the MCDU scratchpad.	Put a note or sticky on radar screen. Or could put something on FMS to remind.
Expect Clearances	What procedures do you currently use for EXPECT clearances?	See above. Same procedure.	If radio loss then give a clearance. Put a note.
Flight Standards - CPDLC Procedural Compliance			
CPDLC Compliance	How would your airline check crews on compliance?	Both need to confirm the clearance verbally. If CPDLC both need to read independently (with exceptions in terminal and taxi environment). Although read independently, both pilots should not do it at the same time. The aircraft must be under positive control at all times.	Maintain communication discipline. Adherence to training. Respond to ATC without compromising operation safety. One pilot MUST always be in command of the aircraft at all times.

3.4.3. Crew Procedures

The results of task analysis are presented in Table 3-8.The analysis of crew procedures assumed trajectory based operations with CPDLC. Each issue observed is listed together with example UMs that are used as background to discuss performance limitations and capabilities across model types and their implications.

Table 3-8. Limitations and Capabilities by UM and HMI Issue.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Compliance with Clearance	General	**B787/ B777/ 733/ B744/ All Models**	When a clearance includes a provision to "CROSS [position] AT" or "AT OR ABOVE/BELOW [level]," the manner in which the descent is executed to comply with the crossing altitude is at the pilot's discretion. Authorization to descend at pilot's discretion is only applicable to that portion of the flight to which the crossing altitude restriction applies, and the pilot is expected to comply with the crossing altitude as a provision of the clearance. Any other clearance in which pilot execution is optional will so state "AT PILOT'S DISCRETION."	Many of the UM clearances allow the pilot to change altitude and adjust speed to best suit the needs of the crew. In the future, TBO may require a compromise between the desires of the crew and the needs of the higher density traffic. The increased traffic will necessitate reducing the latitude given to the crew for altitude changes and speeds.
Compliance with Clearance	UM056: CROSS [position] AT OR LESS THAN [speed]	**All Models**	The crew may get a clearance too soon and may not want to execute on the clearance. If they want to wait, they will have to remember. In other words, there is a CROSSING restriction for a waypoint of a slower speed, but if the waypoint is 100 miles ahead, the crew may want to wait to get closer to the waypoint before slowing to the waypoint speed constraint.	Pilot may forget restriction. Use of STANDBY may be appropriate. A possible solution is to REJECT and resend the clearance close to the waypoint.
Compliance with Clearance	UM049: CROSS [position] AT AND MAINTAIN [level]		Inputting the clearance into the FMS may start the climb earlier than the crew wants, because setting the cleared altitude (e.g., FL350) in the MCP ALT window and setting the altitude (e.g. 350) in the VNAV CRZ page and clicking EXEC will start the aircraft climb to 350.	The FMS will climb the aircraft as soon as the new clearance altitude is entered in VNAV page, and the MCP ALT window is set. If the crew wants to delay the climb, it is recommended that the MCP ALT window be used to initiate the climb.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Compliance with Clearance	UM106: MAINTAIN [speed]	**All Models**	The autopilot is designed to follow speed changes from the FMS and from the MCP. If you are in a climb and put speed in VNAV climb page, then as soon as you level off you will go to VNAV Cruise speed which is higher. NOTE: entering the new speed in the VNAV pages will not cause speed valued in the UM message to change to green. Only changing the IAS/MACH window will cause the speed value to turn green.	Could result in exceeding the speed clearance. If you enter a speed/altitude pair on a cruise waypoint it will turn that waypoint into a climb or descent waypoint. If you enter a speed-only value (Mach-only, CAS is not supported) then that will be a new cruise speed target that will apply after that waypoint (this feature is called Cruise Speed Segments and may not be available on the 747-400 FMS). Prior to reaching the level-off altitude displayed in CRZ ALT parameter in the CLB page the FMS is in the climb mode [MCP ALT value is set lower than the CRZ altitude], then the FMS will maintain the airspeed displayed in the SEL SPD parameter of the VNAV CLB page.
Compliance with Clearance	UM084: AT [position] CLEARED [procedure name]	**All Models**	The arrival procedure (STAR) must be associated with a runway selected in the FMS.	If the [procedurename] contained in UM84 is not associated with the runway selected in the FMS, then the CPDLC system will reject the UM. Crew may get into a troubleshooting mode "what is the system doing now?"
Conditional Clearances	UM065: AT [position] OFFSET [specified distance][direction] OF ROUTE	**747**	On legacy 747-400, the crew must remember to enter the beginning waypoint and ending waypoint for an offset UM defining the start and end positions. The crew may forget to do this. This will have to be handled through procedures and training for legacy types. On 737-300, the crew can program an offset for the beginning and end waypoint.	Many conditional clearances cannot be programmed directly into the FMS such as "AT [time] or [level] PROCEDE DIRECT TO [position]." The newest generation FMS on the 777 and 787 will alert the crew of the condition (time or level). Procedures should help mitigate the potential for crew forgetting a conditional clearance. It is recommended that crews consider printing the clearance and clipping to yoke as a ‘post it’ reminder.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Conditional Clearances	UM188: AFTER PASSING [position] MAINTAIN [speed]		The UM requires crew to remember a future clearance. The crew may forget. Also, typing speed into the VNAV CRZ page but not executing is a potential error waiting to happen.	Entering a higher speed than the ECON SPD (321kts) in the VNAV CLB page does not increase the airspeed above 321kts. Entered 330/15000 as crossing restriction at ANX. The FMS continued 321 kts and leveled off at 15,000ft prior to ANX, crossed ANX, then continued the climb. Recommend executing this clearance with MCP speed intervention and not as an FMS VNAV procedure in a climb. To maintain current airspeed until reaching the AFTER PASSING [position], the crew will not enter a speed into the FMS until passing [position].
Conditional Clearances	UM047: CROSS [position] AT OR ABOVE [level] (climb)	**All Models**	"AT" could be omitted in executing the clearance.	The aircraft will most likely level off at FL270 prior to FRANC and then continue to climb after passing. If 27000 is set in the MCP, the aircraft will level off at FL270. It is recommended that the crew always enter the crossing restriction in the LEGS page.
Conditional Clearances	UM047: CROSS [position] AT OR ABOVE [level] (climb)		On B-787 and B-777, this is a loadable message. Aircraft must be below cruise ALT to see LOAD button come up. The FM logic checks if the aircraft can make the altitude. If the airplane can, then the FM puts up a load prompt on CDU. The system figures out performance for the pilot.	LOAD prompt is not displayed on CDU. Check clearance with respect to present altitude.
Mode Use	UM188: AFTER PASSING [position] MAINTAIN [speed]	**All Models**	For UM188: "AFTER PASSING [position] MAINTAIN [speed]", the FMS VNAV mode will comply with this clearance differently if in the climb phase or in descent phase. A VNAV waypoint speed constraint is interpreted as a "cannot exceed" speed limit, which applies at the waypoint and all waypoints preceding the [position] waypoint if the waypoint is in the climb phase; or all waypoints after it if the [position] waypoint is in the descent phase. [112]	All FMS speed constraints are programmed in VNAV mode to act differently in climb and descent. The intent of the controller and the issued clearance UM must be able to be programmed into the FMS. UM intent and FMS capability must match. The crew is required to understand that to comply with UM188, they will need to manually enter the speed in the MCP or in FMS VNAV after crossing [position].

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Crew Coordination and Workload Reduction	91 HOLD AT [position] MAINTAIN [level] INBOUND TRACK [degrees] [direction] TURNS [leg type]	**All Models**	A hold clearance is most likely to be given during the highest possible workload – missed approach. Approach instructions and procedures are briefed prior to the approach and the controller should clear the aircraft to "hold as published" to simplify the clearance.	The key to crew coordination and workload reduction is dividing the responsibility of flying and communicating with ATC (CPDLC) and an active involvement by the PM.
Crew Coordination and Workload Reduction	UM074: PROCEED DIRECT TO [position]		For loadable UMs, it is necessary to perform a LEGS page verify and "clean up" after accepting the clearance. This should be a crew action and not a system action, because there are too many variables for the system to consider.	As with other route modifications, loadable or not, SOPs should require crews to evaluate the modified route for discontinuities and other operational issues/constraints with flight plan.
Crew Coordination and Workload Reduction	UM074: PROCEED DIRECT TO [position] UM077 AT [position] PROCEED DIRECT TO [position]	**All Models**	The crew must evaluate whether they are within RNP limits.	SOP to emphasize clearance checking so that RNP limits are not exceeded.
Crew Coordination and Workload Reduction	252 CROSS [position] AT [RTAtimesec]		TBO requires reliance on determining and making RTA requirements. Lack of cruise wind information causes FMS RTA calculations to be inaccurate.	Meeting RTA requires accurate winds. The system should allow constant wind updating to improve the accuracy of RTA predictions, or the crew should enter winds when auto-update is not available.
Complex UMs	UM49: "CROSS [position] AT AND MAINTAIN [level] UM50: CROSS [position] BETWEEN [level] AND [level] UM84: AT [position] CLEARED [procedure name]		These can be considered as complex messages because the crew could take some time to understand the UMs and to evaluate the aircraft performance.	Design of procedures should address complex UMs through specialized procedures. Although there are no formal CPDLC definition of a complex UM, there are properties of a UM that could make it difficult to comply with. For example, the number of message elements and the time the crew needs to analyze the performance of the aircraft and constraints on the route due to the clearance. The more time it takes to reply to the clearance the more complex it is.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Pilot/Controller Negotiations	49 CROSS [position] AT AND MAINTAIN [level]	**All Models**	The controller would rather the crew reject a crossing restriction clearance quickly if there is any question that the aircraft will not make the crossing restriction, than delay an acceptance response. If the crew delays an acceptance response, the chances are the controller will have to issue an altitude change or vector to the other conflicting aircraft anyway. The lack of immediate feedback and the CPDLC system delay plus the time spent to check aircraft performance may not be workable for the controller.	The value of immediate feedback during voice communications is not available to the controller during CPDLC. When necessary to reject the clearance due to aircraft performance, it is recommended the crew include a reject reason with their clearance rejection DM. If a reason for not accepting the higher altitude is due to other than aircraft performance, then a free text description of the reason or a voice contact is recommended.
Pilot/Controller Negotiations	UM50: CROSS [position] BETWEEN [level] AND [level]"	**All Models**	This UM is a candidate for negotiations. This clearance in voice communications usually results in negotiations between the crew and the controller. If the crew feels that it might be "tight" making an altitude restriction, they will usually say so immediately. The controller has instant feedback that the crew may not be able to make the altitude restriction. The controller will usually tell the crew to do the best they can, or give them an altitude they can meet, and adjust the other aircraft for separation accordingly. Although there is sometimes lack of formality during negotiations, the JO 7110.65 [2, Para 4-2-5. Route or Altitude Amendments] clearly states: "The phrase 'do the best you can' or comparable phrases are not valid substitutes for an amended clearance with altitude or speed restrictions."	Avoid complex UMs as much as possible to avoid negotiations. Reduce the delay time by simplifying the UM. To reduce the delay, the use of pilot decision tools built into the FMS will prove valuable.
Pilot/Controller Negotiations	General		The FMS for B-733 and B-744 will display "UNABLE NEXT ALT" scratch pad message if it calculates that the crossing restriction cannot be made. But this only occurs after selecting executing the modification (clicking EXEC key).	
Pilot/Controller Negotiations	UM020: CLIMB TO [level]		When a step-climb clearance is received, the crew should verify the altitude is within the aircraft performance capabilities before accepting the clearance.	This could lead to the acceptance of a clearance outside the aircraft performance capabilities.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Use of STANDBY Standardization	DM2: STANDBY		DM2:STANDBY can be sent if the response of the UM evaluation is expected to be longer than one minute (for example).	The use of DM2: STANDBY should be standardized to improve the continuity of CPDLC communication. The use of STANDBY has the potential of injecting instability into a closely spaced process. It may be that STANDBY (in a CPDLC context) should not be used for some critical phases of flight where quick and timely communications are necessary. In some phases of flight (e.g. inside of FAF, taxi phase, etc.) the crew may need to go to voice rather than use STANDBY if a delay in crew response is expected. Reverting to voice allows for quicker resolution of the communication or clearance. There is a compromise between using STANDBY and reverting to voice communication.
Too Long Response Time	UM84: AT [position] CLEARED [procedure name] and UM252: CROSS [position] AT [RTAtimesec]	**All Models**	These clearances have the potential for long response times that could 'TIME OUT' the message, creating further crew confusion.	The use of STANDBY could cause a worse situation. The controller may not have the time to delay the crew response with STANDBY, but the clearance has already been given to the crew. In that case, the controller may have to revert to voice communications or send a UM to disregard the last UM clearance.
Display Procedures	UM020: CLIMB TO [level]	**B787/ B777/**	If an accepted UM remains displayed when a new UM is uplinked, then the crew is alerted by a chime and "ATC" is displayed in the EICAS page, but the new UM is not displayed in the AUX panel (787) or ECAS display (777). This may cause the crew to miss an ATC clearance.	The CPDLC set-up should not lead the crew to miss an ATC clearance. The crew should have a default (or standard) datalink set-up after each UM clearance has been responded to. After loading, executing and accepting the uplink message, the crew should clear the UM displayed in the EICAS or MFD. In the case of the B-777 they should have the COMM Manager up full time so that the load prompt is clearly visible.
Display Procedures	General	**787**	It is easy to click on the CANCEL button instead of the LOAD button in the B787 Loadable Pop-Up menu. The LOAD prompt goes away and crew may get confused about the clearance.	Inadvertent activation of the wrong button could lead to an error. Active participation of both crewmembers may mitigate this issue.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Display Procedures	General	**All Models**	Crew may not wait for ACCEPTED to turn green before canceling; which is the crew's 'receipt' that ground has received your downlink response.	The crew should wait for 'ACCEPTED' to turn green before canceling, which is the crew's 'receipt' that ground has received your downlink response.
Speed Control	UM 258 CROSS [position] AT OR AFTER [RTAtimsec] AT [level]	**All Models**	The FMS only adjusts speed to meet the RTA time restriction during cruise, not during climb or descent. Using the FMS VNAV mode may not be the best selection for many speed clearances in these phases of flight.	UM258 should not be used as a climb or descent clearance. A climb or descent clearance should include the phrase "AT AND MAINTAIN [level]" to reduce any confusion that the crew should level off at the clearance altitude. The crew should maintain ATC speed clearances, such as UM310: "AT [level] MAINTAIN [speed]," using the MCP panel, and use FMS speed restrictions from published departures and arrivals.
VNAV	UM 47 CROSS [position] AT OR ABOVE [level]	**All Models**	If the crew does not have VNAV mode engaged on the MCP, the FMS will still load the UM, but the guidance/autopilot will only fly what is selected on the MCP and not follow the navigation and constraints provided by the FMS to meet the altitude restriction.	TBO requires extensive use of VNAV for altitude and speed restrictions. Automation mode awareness is an important factor that should be considered in procedure design.
VNAV	ALL		If CPDLC will be used to load altitude clearances, then the crew must fly the aircraft in VNAV mode. Crews normally do not like to climb or descend in VNAV mode because VNAV tends to control the aircraft more abruptly than the MCP modes, and in VNAV the aircraft tends to pitch up and down to give a less comfortable ride. Therefore crews will tend to use vertical speed (VS) during climb at the higher flight levels and flight level change (FL CH) during descent.	VNAV tends to control the aircraft more abruptly than MCP modes, and in VNAV the aircraft tends to pitch up and down to give a less comfortable ride. Design VNAV to provide a more comfortable ride.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Loadable	UM50 CROSS [position] BETWEEN [level] AND [level]	**B787**	UM50:"CROSS [position] BETWEEN [level] AND [level] " is only loadable on the B787. UM20:"CLIMB TO [level]" is NOT loadable, but is dialable. When the crew receives UM20 concatenated with UM50 they will dial in the cleared altitude from UM20 and load the altitude restriction contained in UM50.	Potential issues are (i) During a TA or CDA, will the FP or the NFP perform the head's down work with the FMS?; (ii) Should the CPDLC/FMS software check for appropriateness, setup all the navigation parameters and the crew execute the clearance and acknowledge the clearance? Procedures should be developed that enable the flight crew to evaluate loadable UMs accurately and quickly to prevent complacency.
Intermediate Level Off	20 CLIMB TO [level]	**All Models**	When the crew initializes the FMS during preflight the cruise altitude is entered in the CRZ ALT parameter in the CRZ page. Standard procedure for intermediate level off is to dial the cleared altitude in the MCP Altitude Window and not change the altitude value in the CLB or CRZ pages. The intermediate level off procedure is currently taught by most airlines and flight academies, such as Pan Am Flight Academy in Miami, FL [66]. The same procedure is used during descent. Aircraft performance is not an issue on descent, but lower altitude factors such as turbulence and excessive fuel burn are considered by the crew.	Continued use of the intermediate level off procedure is recommended for CPDLC operations.
Climb and Descent	20 CLIMB TO [level]	**All Models**	When a step-climb clearance is received, the crew should verify the altitude is within the aircraft performance capabilities before accepting the clearance.	When necessary to reject the clearance due to aircraft performance, it is recommended the crew include a reject reason with their clearance rejection DM. If a reason for not accepting the higher altitude is due to other than aircraft performance, then a free text description of the reason or a voice contact is recommended.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Climb and Descent	50 CROSS [position] BETWEEN [level] AND [level]	**All Models**	UM50: "CROSS [position] BETWEEN [level] AND [level]", altitude restriction clearance is very seldom used in flight plan-based ATC operations because it requires the controller to manually "thread the needle" (aircraft) between two other aircraft. This decreases the margin of error and increases the risk of conflict. It is safer and easier to vector an aircraft instead of stacking three aircraft on top of each other while climbing or descending.	For NextGen TBO, reduced RNP, and aircraft-based separation equipment, this UM may be necessary for increased traffic volume. But in a purely manual separation environment, the controller probably will not use this UM.
Required Time of Arrival (RTA)	258 CROSS [position] AT OR AFTER [RTAtimsec] AT [level]	**All Models**	The “AT OR AFTER” crossing restriction is the easiest RTA restriction to obtain because it only requires delay crossing a waypoint. Increasing speed to “make up time” is much more difficult. The FMS only adjusts speed to meet the RTA time restriction during cruise, not during climb or descent.	UM258 should not be used as a climb or descent clearance. A climb or descent clearance should include the phrase “AT AND MAINTAIN [level]” to reduce any confusion that the crew should level off at the clearance altitude. It is recommended that ATC not use UM258 as a climb constraint because of the design issues described above. It is recommended that ATC use UM258 as a cruise constraint and only if the aircraft is an hour or more from TOD. RTA prototypes are being developed for Airbus (A320) and B757 that can meet RTA in climb or descent phase.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Required Time of Arrival (RTA)	258 CROSS [*position*] AT OR AFTER [*RTAtimsec*] AT [*level*]	**All Models**	For a fixed Mach, a 2,000 foot change in altitude changes the TAS by approximately 5 kts. For example, if you hold .75 Mach, climbing from FL330 to FL370 will decrease TAS by 10 kts. Meeting RTA time constraints is much more difficult due to the varying winds at different altitudes and entering that information into the FMS. A .01 change in Mach equals 5 to 6 kts. of TAS. To gain 1 minute over 1 hour, will require an increase from .76 Mach to .775 mach. To gain 2 minutes - will require an increase from .76 Mach to approximately .79 mach. For a given Mach number above the IAS to Mach climb cross over point (narrow body FL 250, wide body FL 270), climbing decreases TAS, while descending increases TAS.	Crew should maintain updated wind information in the FMS for RTA operations.
ATC Speed Compliance	106 MAINTAIN [speed]	**All Models**	ATC will express all speed adjustments in terms of kts. based on indicated airspeed (IAS) in 10 knot increments except that at or above FL 240 speeds may be expressed in terms of Mach numbers in 0.01 increments. The use of Mach numbers is restricted to turbojet aircraft with Mach meters. [43: 4−4−12-b. Speed Adjustments] Pilots complying with speed adjustments are expected to maintain a speed within plus or minus 10 kts. or 0.02 Mach number of the specified speed. [43: 4−4−12-c. Speed Adjustments]	TBO may require more restrictive speed requirements, such as plus or minus 5 kts or 0.01 Mach.
Speed Clearances	56 CROSS [position] AT OR LESS THAN [speed]	**All Models**	If the controller gives UM56: "CROSS [position] AT OR LESS THAN [speed]" as a clearance, then the crew may ask "Can we “keep the speed up” until just prior to crossing waypoint?” Answer: The fact that the controller gave the clearance to cross a waypoint at a given speed implies that before the waypoint the speed is at pilot’s discretion.	It is recommended that the crew not load UM56 or UM61 into the FMS for a speed restriction during climb. They should navigate using the MCP to meet the intent of the clearance. Loading and navigating UM56 during descent is recommended.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
	UM061: CROSS [position] AT AND MAINTAIN [level] AT [speed]	**All Models**	UM61: "CROSS [position] AT AND MAINTAIN [level] AT [speed]" is not loadable, yet. This is the same issue as UM56. In a climb, the FMS will immediately slow. The FMS will not increase speed greater than the TGT SPD in the VNAV CLB page.	If the speed restriction is immediately entered, then the aircraft will start slowing down immediately. The clearance gets uplinked as a MACH but the 787 FMS cannot accept a MACH tied to an altitude. This has the potential for confusion. The main issue is: when does pilot slow down? It is recommended that the crew not manually enter the speed restriction into the FMS during climb. The crew should navigate using the MCP to meet the intent of the clearance. Loading and navigating UM61 during descent is recommended. Intermediate level-off procedures are recommended.
Offset Clearance	64 OFFSET [specified distance] [direction] OF ROUTE	**All Models**	UM64: " OFFSET [specified distance] [direction] OF ROUTE": Offset is used not only for side-stepping weather, it is also used by ATC for RNAV routes as described in the *Aeronautical Information Manual* (AIM). Unpublished RNAV routes are direct routes, based on area navigation capability, between waypoints defined in terms of latitude/longitude coordinates, degree−distance fixes, or offsets from established routes/airways at a specified distance and direction. [AIM 5-3-4-3(c)] If this UM is to be used to define an RNAV route based on an offset from an established route/airway, then the [route] will need to be defined in this UM. [7110.65, 4-4-i-4] When clear of weather, the crew requests and ATC clears direct to next waypoint. The crew does not want to turn to get back on the original track. There is no desire or need for the crew to return back to the original track.	UM64: " OFFSET [specified distance] [direction] OF ROUTE" should be used only for weather deviation or strategic separation. If the crew requests the offset for weather deviation, ATC should clear the crew direct to next waypoint after deviating. This reduces the amount of deviation required and easier for the crew to select when they can fly direct to the next waypoint. The crew should be advised by ATC when or where the offset will terminate.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Clearance Limit	74 PROCEED DIRECT TO [position] 77 AT [position] PROCEED DIRECT TO [position]	**All Models**	In accordance with the AIM, when UM74: “PROCEED DIRECT TO [position]" is issued as a standalone, [position] is considered the clearance limit. The AIM states: “When an aircraft is 3 minutes or less from a clearance limit and a clearance beyond the fix has not been received, the pilot is expected to start a speed reduction so that the aircraft will cross the fix, initially, at or below the maximum holding airspeed.” [FAA AIM 4-4-3-e-4, and 5-3-7-d]	UM74 or UM77 should be concatenated with holding instructions, EFC, full route clearance after the direct to waypoint or rest of route unchanged (UM289). ATC should append UM289 to UM74 when the controller intends to clear the aircraft in its current route after the position in the DIRECT TO [position] is reached. In this case the datalink avionics and FMS should display only the changes to the pilot of the new route clearance.
Stand-Alone Uplink Message	UM47: "CROSS [position] AT OR ABOVE [level]" UM49: "CROSS [position] AT AND MAINTAIN [level]" UM50: "CROSS [position] BETWEEN [level] AND [level]"	**All Models**	The controller could possibly send an altitude restriction clearance without the complete context of a "cleared to" altitude limit or a route clearance limit.	Crews should be aware of clearances (such as UM47) that are sent without context of a concatenated UM or previous clearance. UM47 should be concatenated with UM20 to avoid any ambiguity or crew misunderstanding. All UM clearances should follow the rules defined in the 7110.65 ATC Manual. When route or altitude in a previously issued clearance is amended, ATC is required to restate all applicable altitude restrictions. (Order 7110.65T, 4-2-5.b). When route or altitude in a previously issued clearance is amended, ATC is required to restate all applicable altitude restrictions. [2: 4-2-5.b].
Stand-Alone Uplink Message	UM74: "PROCEED DIRECT TO [position]" UM77: "AT [position] PROCEED DIRECT TO [position]"		UM74 or UM77 should not be sent as a stand-alone because the crew is would be expecting a clearance limit.	Unless this DIRCT To [position] is the destination airport, this UM should be concatenated with a clearance route or UM289. SPR Ver.H, Sect 5.2.6.3 states that UM74 can be used with “UM72: RESUME OWN NAVIATION”. To avoid confusion by the crew, “UM289: REST OF ROUTE UNCHANGED” should be used. It can be confusing to have two UMs that mean about the same thing. Any ambiguity must be eliminated to avoid pilot error.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Concatenation Rules	20 CLIMB TO [level] + 116 RESUME NORMAL SPEED		The concatenation of two or more UMs can be interpreted to be performed sequentially or in parallel. ATC will include a message modifier (UM165: THEN) between UMs to signify the UMs are to be performed in order and sequentially. In this example the crew is to interpret the clearance as two separate clearances performed at the same time. Therefore the crew will begin their climb and return to their normal climb speed.	It is recommended that the controller order concatenated UMs to minimize sequential or parallel execution ambiguity.
UM Clarification	20 CLIMB TO [level] 47 CROSS [position] AT OR ABOVE [level] 49 CROSS [position] AT AND MAINTAIN [level]		The uplink messages should be as unambiguous as possible for the crew.	To clarify altitude requirements, UM20 must be concatenated with crossing restriction and re-route UMs. Therefore, UM 20 should read: "CLIMB TO AND MAINTAIN [level]."
UM Clarification	61 CROSS [position] AT AND MAINTAIN [level] AT [speed]		If the controller intends the crew to climb to FL350, and to cross a waypoint at FL290, then the controller could use UM27: “CLIMB TO REACH [FL290] BY [position]" as a crossing restriction clearance. The complete concatenated example is: UM20: "CLIMB TO [FL350]" + UM27: "CLIMB TO REACH [FL290] BY [position]"	UM27 should be preceded byUM20: CLIMB TO (AND MAINTAIN) [level]. The use of UM20 is unambiguous and should precede (concatenated with) altitude restrictions
UM Clarification	290 DESCEND VIA [procedure name]		UM290: "DESCEND VIA [procedure name]" will assign an arrival procedure (STAR, TA, CDA, etc.) to the aircraft. If the UM is sent by itself, then the crew must assume the descent is at pilot’s discretion	It should be clear to the crew that they are cleared to an altitude and they can begin the descent at pilot’s discretion. The crew need’s a “cleared to” altitude from ATC to enter into the MCP ALT window. An example of the concatenated message set to clear the crew to begin the arrival procedure is: UM23: DESCENT TO [level] + UM144: AT PILOTS DISCRETION + UM290: DESCENT VIA [procedure]

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
UM Clarification	295 AT [position] CLIMB VIA [procedure name]		UM295 is ambiguous. If the crew receives this UM, they will have several issues: 1.) There must be an altitude to climb to and maintain 2.) Can the crew begin the climb now, and when they get to [position], continue the climb via the [procedure name]? Note: there is no mention of this type of clearance in the Air Traffic Control ORDER JO 7110.65	UM295 requires UM20 to provide a clearance altitude limit. If UM20 is concatenated with UM295, then there is still confusion: CLIMB TO [level] + AT [position] CLIMB VIA [procedure] The above clearance instructs the crew to begin climb now, and when you get to [position], then continue your climb via [procedure]. UM295 should have explicit information to make it as unambiguous as possible, and be concatenated with any other clearance that describes exactly what the controller expects them to do. Each UM (or concatenated clearance) should provide verbatim compliance instructions for the crew to follow. UM295 should read: “AT [position] CLIMB AND MAINTAIN [level] VIA [procedure name].” The complete ATC clearance should read: “MAINTAIN [level] + THEN + AT [position] CLIMB AND MAINTAIN [level] VIA [procedure name].”
Complex UMs	61 CROSS [position] AT AND MAINTAIN [level] AT [speed]		UM61: is clear that the controller wants the crew to cross [position] at and maintain 15,000 ft, but the crew may understand that the speed until [position] is at pilot’s discretion and after [position] the crew is to maintain 280 kts. But another crew may associate “MAINTAIN” to only the altitude and not the speed and fly at 280 kts to [position], then speed back up after [position]. This is exactly what the FMS does in the climb with this climb restriction.	It is recommended that the UM61 read: CROSS [position] AT AND MAINTAIN [level] AND [speed]
Complex UMs	UM255: "CROSS [position] BETWEEN [RTAtimesec] AND [RTAtimesec]"		There is currently no FMS that will accept user input to cross a waypoint between two times (i.e. time window). It is not likely that FMS OEMs are considering including this feature in an FMS.	It is recommended that UM255 not be used for crossing constraints.

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Complex UMs	UM258: "CROSS [position] AT OR AFTER [RTAtimsec] AT [level]"		UM258 has multiple variables, which could make it an ambiguous clearance. During a climb, the FMS does not calculate RTA speed and this could cause confusion.	Use simpler clearances. UM258 should not be used as a climb or descent clearance. A climb or descent clearance should include the phrase "AT AND MAINTAIN [level]" to reduce any confusion that the crew should level off at the clearance altitude.
Pilot Discretion	27 CLIMB TO REACH [level] BY [position]		Some UMs imply pilot discretion on how and when to comply with the clearance. UM27 is an example. UM27 is a "backwards" crossing restriction that gives the discretion to the crew where they will reach the clearance altitude. CLIMB TO REACH [level] BY [position] is difficult for CPDLC to load into the FMS because there is no specific waypoint to be "AT AND MAINTAIN." To load a UM with the intention of UM27 into the FMS, a new along-track waypoint is created prior to [position] and loaded, then send UM47: "CROSS [position] AT OR ABOVE [level]," where [position] is the new along-track waypoint.	TBO will limit the use of pilot discretion for climb, descent, and route modification. The controller and ATC ground applications need to know the current and future flight path of all aircraft.
Pilot Discretion	290 DESCEND VIA [procedure name]		UM290: "DESCEND VIA [procedure name]" will assign an arrival procedure (STAR, TA, CDA, etc.) to the aircraft. If the UM is sent by itself, then the crew must assume the descent is at pilot's discretion.	It should be clear to the crew that they are cleared to an altitude and they can begin the descent at pilot's discretion. The crew need's a "cleared to" altitude from ATC to enter into the MCP ALT window. An example of the concatenated message set to clear the crew to begin the arrival procedure is: UM23: DESCENT TO [level] + UM144: AT PILOTS DISCRETION + UM290: DESCENT VIA [procedure]

Issue	UM Example	Model	Performance limitations and capabilities across model types	Discussion and Implications
Pilot Discretion	UM 20 + UM 116 CLIMB TO [FL230] + RESUME NORMAL SPEED		In the NextGen TBO environment, it may be necessary for ATC to have the aircraft fly a predictable ECON airspeed. The ECON speed changes throughout the flight and can be predicted by ATC TBO tracking and management software.	UM116 should mean that ATC expects the crew to maintain a constant normal airspeed. A normal speed could be the FMS computed ECON airspeed, or another constant airspeed deemed appropriate by the crew. In any case, ATC does not expect the crew to be changing the speed. This will become important during NextGen TBO. A recommendation is to modify UM116: RESUME AND MAINTAIN NORMAL SPEED
Pilot Discretion	UM 20 + UM 116 CLIMB TO [FL230] + RESUME NORMAL SPEED		When 230 is entered in CRZ ALT, the CLB page automatically selects ECON SPD (324/.661) and illuminates the EXEC key.	The policy should be to leave the final CRZ altitude in the VNAV page at FL330 and make level-off changes using the MCP ALT window.

3.5. Summary of Observed Pilot System Issues

Although, with N=2, this is not a formal study of pilot error and recovery, the engineering analysis of HMI differences and crew responses to system behavior indicated, at least anecdotally, that some system actions may bias the crew into making errors. These observations will be useful when constructing the scenario for Phase II of this contract.

1. Multiple UMs with similar sounding phraseology but requiring different actions may cause procedural confusion for the crew.
2. The crew may not comply with a “complex” clearance due to misunderstanding of the UM.
3. Pilot will not be aware of what SC214 messages are FANS 1A and which are ATN. FANS 1A have a 40 second time-out. Delayed pilot responses to that message type will cause unnecessary response delays to an ATC clearance. Crew may over-analyze a UM, take too long to reply, and exceed the time out.
4. Some complex UMs may require extensive configuration set-up (e.g., extended route clearances) and evaluation leading to message or clearance timeout.
5. Assuming a clearance is "at pilot discretion" when it is not.
6. Missing the condition to initiate the clearance action.
7. Crew may comply with a clearance without evaluating operational impacts. Crew may accept a clearance outside of the aircraft’s performance envelope.
8. Crew may implement clearance too early with unintended consequences.
9. Crew NOT providing a reason for rejection (e.g. aircraft performance) thus increasing possibility of unnecessary further CPDLC communications.
10. On B-787 LOAD and CANCEL buttons are right next to each other. Pilot may inadvertently activate CANCEL causing an unnecessary delay in responding to ATC.
11. Crew may not clear a display after responding to a clearance, with the result that the next incoming ATC message may not be noticed.
12. Crew may not wait for CPDLC display to indicate that ground has receipt of message. They may blank the display and assume that there was a handshake with the ground when in fact there was not.
13. Inadvertent use of STANDBY; Using it when it is not required, leading to delays and not using it when it is required leading to timing out of clearance. PM may not recognize or verbalize the use of STANDBY.
14. Crew may attempt to use FMS for speed control. There are many traps when using FMS for speed control, especially in climbs or descents. Entry of a speed restriction on the LEGS page can cause inadvertent speed changes not anticipated by the crew.
15. Setting a conditional (AT Waypoint) altitude restriction on the LEGS page with VNAV engaged. Aircraft will begin climbing early.
16. Crew may not be aware of the flight guidance mode.
17. Crew not understanding how the FMS controls the aircraft speed for VNAV waypoint speed constraints.
18. If the UM requires an OFFSET to begin at a specified distance or waypoint downpath, the pilot may attempt to create a longitudinal or user waypoint to satisfy the clearance leading to response delays and errors.
19. Crew may not check RNP for route modifications. May ‘load and forget.’ Tendency may be stronger for loadable route modifications, especially under time pressure.
20. DIRECT TO clearances may create discontinuities that are not checked and closed by the crew.

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4. Recommendations

4.1. CPDLC Crew Procedures

4.1.1. Standardization

CPDLC changes the way the captain manages the crew, the cockpit, and the flight. Like all new technology, the challenge is to manage the technology and the increased information it provides. Proven cockpit resource management (CRM) principals play a vital role in defining operational philosophy and policy to ensure an effective cockpit work environment. When considering CRM principles, standardization becomes a vital CRM tool. Standardization helps to ensure compliance with policies and procedures.

Military and airline flight departments have shown that the most effective and safest operations occur when a high level of planning, crew support, and standardization exist. The use of standard procedures and terminology reduces the burden of planning and promotes crew confidence and cockpit discipline. The recommended level of CPDLC standardization should be high enough to discourage unsafe practices, carelessness, and the development of individualized procedures, but not so restrictive that operational flexibility, good judgment, and professionalism are discouraged. Thus, the policies and procedures recommended herein provide a foundation for CPDLC procedures.

Because CPDLC technology provides many different modes of operation, we recognize that the pilot's personal style or technique for completing a task cannot, and should not, be inhibited.

4.1.2. Philosophy

Research presented in [23] and [24] focus on the philosophy, policy, and the design of cockpit procedures. The authors suggest that failure to develop an overall philosophy and set of policies that are consistent with each other, and procedures that are consistent with both, will lead flight crews to deviate from SOP. Furthermore, attempting to shortcut the three Ps process described in the references has the risk of generating a set of ill-conceived and inconsistent procedures. Based on this motivation, the framework of the three Ps process was applied to the development of CPDLC procedures in this study.

The following top-level philosophies for CPDLC are incorporated into the procedural recommendations:
- Maximum operational safety and efficiency should be maintained at all times during flight operations.
- A human-centered approach should explicitly focus on issues of human performance and cooperative performance of humans and flight deck automation related to CPDLC.
- The human is ultimately responsible for the safe operation of the aircraft (i.e., the flight crew has final authority in accepting or rejecting clearances). Beyond this basic premise, the CPDLC philosophy is agnostic as to how automated systems and the flight crew jointly achieve maximum operational safety and efficiency (for example, loadable vs. non-loadable clearances).
- CPDLC is an effective tool, but not the only tool to communicate with ATC.
- Pilots are the best judges of the optimal implementation and use of CPDLC on the flight deck.

4.1.3. Policy

The philosophy in turn generates policies for specifying how management expects tasks to be performed [23, 24]. Based on the preceding philosophy statements, the following CPDLC-related policies were identified to guide the development of procedures in this study:
- Clear and concise guidance should be provided for when CPDLC will be used and when voice will be used. This policy could be tied to phase of flight, altitude or workload level.
- CPDLC should not interfere with normal crew callouts.
- CPDLC responses should be timely.
- CPDLC training should emphasize the importance of a timely crew response to uplink ATS messages [103]

- Effective and recent CPDLC training should be provided. CPDLC training should emphasize key CPDLC issues:
  - Training should emphasis and re-enforce that EXPECT clearances should not be loaded pre-maturely.
  - If the flight crew determines they will need a significant amount of time to respond to a message, they should send a **DM2:** STANDBY response. [55]
  - If the flight crew has sent a **DM2:** STANDBY response, they should provide a closure response to the uplink within a reasonable period of time, for example five minutes, or as required. [15]
  - Training should emphasize the appropriate allocation of flying tasks and communication tasks between flight crew.
  - Training on CPDLC procedures should emphasize that CPDLC operations should not require the simultaneous visual attention of both pilots.

- The flight crew should have an equivalent level of situational awareness associated with understanding the content and intent of a message in the same way as when using voice communication [GOLD document].
- A clear understanding of the clearance is required by both pilots. The flight crew should coordinate the assessment, response decisions, and execution of clearances.
- To minimize CPDLC errors, each flight crew member should independently review uplink messages and verify downlink messages.
- Flight deck discipline and crew coordination should be maintained so that CPDLC does not adversely affect crew workload.
- Pilot's judgment will determine when and how the crew will respond to uplink messages.
- Positive delegation of monitoring responsibilities is as important as positive delegation of flying responsibilities.
- CPDLC can be used to negotiate; however, the PIC maintains the authority to use voice or CPDLC depending on time pressure, crew workload, or the capability/limitations of CPDLC to communicate complex negotiations.

4.1.4. Procedures

The policies listed above, together with other sources of information described in this report, guided the team in developing the procedures detailed in the next section of this report. In conformance with the three Ps process, these procedures addressed these questions:

- *What is the task?* Specific DMs and UMs are used for each procedure step to illustrate the required task and provide context.
- *When the task is conducted (time sequence)?* A phase of flight sequence from gate-to-gate was used.
- *By whom it is conducted?* For each procedure step, the responsibility for the pilot flying and pilot monitoring are defined.
- *How is the task done (actions)?* Is voice or CPDLC recommended and, if CPDLC is recommended, what are the required tasks?
- *What is the sequence of actions?* Sequence of tasks for UMs and DMs are described.
- *What type of feedback is provided?* Feedback associated with pilot actions is described.

The recommended procedure analyzes CPDLC UMs from an end-to-end perspective. When an ATC uplink is sent to the on-board CPDLC system, it is necessary to understand the crew tasks required to configure the automation to comply with the ATC clearance within the context of the phases of flight.

Justifications and explanations based on the study (e.g. literature review, limitations and capabilities, human factors principles and simulator observations) are provided for each recommendation.

4.2. Recommended Crew Procedures

4.2.1. Overview

A phase of flight format was used to develop CPDLC procedures. The phases began at the gate and progressed through pushback, ramp taxi, taxi to the runway, takeoff, initial climb, and so on. The phases ended with approach and landing at the destination airport. Critical events were embedded (e.g., crossing runways, or approaching altitude capture) within each phase. Other crew tasks were also included in each phase of flight (for instance aircraft configuration, use of checklists, etc.) so that the overall context for the receipt and response to ATC uplinks could be better understood. This process allowed crew procedures to be developed within the overall context of a particular phase of flight, and its associated crew tasks and the ability to evaluate a wide range of ATC uplink message types (e.g., concatenated uplinks, conditional uplinks, expect clearances, RTA, and several climb, cruise, speed and route uplink clearances).

The recommended procedures are included in tables organized by the sequence of flight phases and labeled by capital letter and events during the phase are numbered. The tables contain recommendation for use of voice or CPDCL. For CPDLC use, the tables use representative uplink message clearances to illustrate recommended procedures.

The following is a table of contents for the Phase of Flight Analysis and Recommendations:

2. Passenger Announcement
3. Navigation
4. Out of Sequence Messages
5. Large Clearance Reroute
6. Negotiation for Large Reroute
7. Conditional Clearance
8. RTA Clearance
9. Crewmember Leaves the Cockpit
10. Weather Deviations
11. Crew Meals
12. D-ATIS
13. Setup FMS for Descent and Approach
14. Approach Briefing
15. Top of Descent

E. DESCENT

1. AOC In-Range Call
2. Transition Level
3. In-Range Checklist
4. Intermediate Level-Off Altitude
5. Approach Change
6. APU Start
7. Setup for Bleeds-off Approach
8. Data Link Altitude
9. 10,000 feet Altitude Callout
10. Approach Checklist
11. Final Approach

F. LANDING

1. Final Approach
2. G/S and LOC Alive / Capture
3. Final Approach Fix
4. Landing Checklist
5. Altitude Callouts
6. Decision Altitude
7. Transition to Visual Cues
8. Landing

G. MISSED APPROACH

1. Go-around
2. Missed Approach Procedure
3. Holding
4. Return for Landing or Diversion

4.2.2. Assumptions

The following assumptions underlie the premise for the recommended CPDLC procedures:

- Recommended procedures are based on current equipage with B-787, B-777, and Mark II CMU for legacy aircraft.
- Although new technology are expected as part of NextGen (e.g. AMM, FIS-B, HUD Taxi Graphical), these technologies are a few years from certification and will not see widespread use for the near term. Therefore, the recommended procedures are based on current technology and limitations applicable to datacomm.
- Recommended procedures in this study assume normal operations and do not cover non-normal or off-nominal operations.

- Normal cockpit flow procedures are done by memory and scan and backed up by normal checklists.
- All aircraft systems are assumed to be operating normally and all automated features are utilized, when appropriate.
- The FMS may or may not have auto-load capability.
- Two-pilot flight crew operation is assumed.
- The phase of flight analysis reported in Section 3.4.3 of this report took into account current departure and approach procedures. Some procedures still in trial and/or development were not included in this report. These were:
  - Constant descent approach
  - Tailored arrival
  - Merging and spacing procedures
  - Cold weather operations

4.2.3. Operational Definitions

Table 4-1 lists the operational definitions that are used in all procedures.

Table 4-1. Operational Definitions

Item	Term	Definition
1	Verify	To establish the accuracy and validity of data entered by a crewmember in the aircraft automation. Verification will be performed independently by a crewmember to compare what is understood to be a correct clearance or correct data against their dispatch paperwork and/or data entered into the aircraft's avionics.
2	Evaluate	To determine the operational or safety implications of a clearance and the ability of the aircraft automation to execute the clearance. A crewmember will independently determine if the clearance is appropriate for the current conditions, aircraft performance, operational requirements, or pilot discretion. Can the aircraft accomplish the clearance? Based on current operational circumstances, company policy, etc. "Do we want to do it?" Sometimes to evaluate a route modification the route mod should be loaded but not executed (e.g. LNAV mods). But VNAV must execute the change to determine if the aircraft can perform the clearance.
3	Discuss	The goal of the discussion is to verbalize the clearance evaluation so that a common shared awareness is created. The crew should come to a mutually agreed awareness or understanding of the clearance and evaluation of that clearance and a response decision.
4	Crosscheck	Crosscheck is a verbal procedure to ensure that all data entry is correct for both pilots, that aircraft displays reflect correct data entry, and that aircraft performance is in the correct direction and magnitude. Crosscheck of data entry, display feedback, and aircraft performance requires an acknowledgment by the other crew member.
5	EXECUTE	To press the EXECUTE key on the FMS to make the modified flight plan changes (for both LNAV and VNAV) the active flight plan. Aircraft performance is checked again, and mode annunciations on PFD are monitored for appropriate mode changes. ND is checked for the display of the proper route.

4.2.4. General CPDLC Procedures

The phase of flight analysis includes CPDLC procedure recommendations for all phases of flight. General CPDLC procedures apply to all phases of flight and to all CPCDLC communications. Table 4-2 provides guidance, definitions, and requirements for CPDLC flight deck procedures.

Table 4-2. General CPDLC Procedures

Item	Subject	Description
1	Default Configuration	A "default" or standardized setup for the FMS and CPDLC CMU for the PF and PM should be implemented by the crews/airline. The crew should return to the default set-up for data comm anytime they must access another page on an MCDU or another screen on an MFD. This ensures that data comm is always displaying the active page for new message uplinks.
2	Verify and Crosscheck	When one pilot verifies data, it must be cross-checked by the other pilot.
3	Aircraft Monitoring	After every clearance execution/acceptance, the crew will scrutinize the current and future states of the aircraft. The crew's duties and responsibilities always include monitoring the aircraft response to automation inputs. Therefore, the crew will follow up every clearance UM execution by monitoring the aircraft's response to all automation inputs.
4	Interruptions and distractions	Interruptions (e.g., due to ATC communications) and distractions (e.g., due to a conversation among others on the flight deck) occur frequently during flight. Some cannot be avoided and therefore, the flight crew must cope with them. Other distractions can be minimized or eliminated through training, adoption of effective procedures, discipline, and the use of good judgment. If the number of interruptions and distractions is not minimized or the impact of residual interruptions and distractions is not controlled, flight safety can be affected. In particular, when a flight crew is disturbed while monitoring or controlling the aircraft, errors can go undetected. Specific ways to help control each of the major factors that promote interruptions and distractions include: • Plan PA announcements for low-workload periods. • Keep intra-cockpit communications brief and clear. • Define task sharing when programming FMS and CPDLC. • Plan extended head-down tasks for low workload periods. • Announce when you are going “head down.” • Pay particular attention to the proper completion of normal checklists.
5	Response time and STANDBY	Develop flight crew procedures to respond to uplinks as soon as practical after they are received. For most uplinks, the flight crew will have adequate time to read and respond within one minute. However, the flight crew should not be pressured to respond without taking adequate time to fully understand the uplinked message and to satisfy other higher priority operational demands. [55] • If the flight crew determines they will need a significant amount of time to respond to a message, they should send a DM2: STANDBY response. [55] • If the flight crew has sent a DM2: STANDBY response, they should provide a closure response to the uplink within a reasonable period of time, e.g. 5 minutes, or as required. [55] • If the controller receives a DM 2: STANDBY response to a message and does not receive another response within a reasonable period of time (e.g. 10 minutes) or as required, the controller should send a UM 169 [free text] inquiry rather than resend a duplicate message. [55]
6	Concatenated messages	Concatenated messages must be accepted or rejected as a complete set. The crew should be vigilant that some of the messages are not loadable.

Item	Subject	Description
7	DM monitoring	After sending a DM response to a UM clearance, the crew should monitor the CPDLC status prompt as an indication that the ATSU system has acknowledged receipt of the DM.
8	Clearing the UM list	The PM should clear the UM notification screen as soon as the crew has replied to the UM. Clearing the notification screen allows the next UM to be displayed.

The following section documents the recommended crew procedures by phase of flight. Details of each procedure are given in a table that lists event sequence, pilot flying/pilot in command (PIC) and pilot monitoring/first officer (FO) procedures. The first row of the table gives a procedure number (e.g., A.1), flight phase, and procedure name. The procedure name is highlighted in bright green. The second table row specifies the recommended mode of compliance—voice or CPDLC. The background for the recommendation is color-coded for mode: green for CPDLC and yellow for voice. Details for CPDLC-recommended procedures also have a green background. Certain procedure details are highlighted in red for special emphasis. Notes at the end of the table may be referenced in the procedure detail (e.g., see fourth cell under Sequence of Events in procedure A1, below.).

4.2.5. Recommended Crew Procedures by Phase of Flight

4.2.5.1. Taxi phase

A.1. TAXI	**Preflight Checks at the Gate**	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft is parked at the gate for preflight checks.	Perform PIC preflight check. Check FMS is programmed correctly.	Perform FO preflight checks. Enter the "computer" flight plan in the FMS.
AFN (ATS facilities notification) Logon procedure.	The PIC will get the weather and clearance or delegate to the FO.	Perform AFN Logon procedure
Request for taxi and departure clearance via CPDLC should be done at the gate [Continental 2011]	Should not be necessary for the PIC to verify the **requests** for clearance and taxi routing information.	Perform CPDLC equip check Record / display ATIS. Send: **DM139**: REQUEST DEPARTURE CLEARANCE [*departure clearance request data*] Send: **DM149**: REQUEST TAXI ROUTING INFORMATION
Crew receives route clearance: **UM266:** CLEARED TO [*position*] VIA [*route clearance enhanced*] **Note 10**	Read clearance silently Verify clearance against dispatch flight plan. Crosscheck. Tell FO to accept clearance. Program clearance into FMS. Crosscheck	Read clearance silently Verify clearance matches dispatch flight plan. Crosscheck Send: **DM0:** WILCO - Crosscheck
Crew receives taxi clearance: **UM315:** EXPECT TAXI [*taxi route*] + **UM330:** [*graphic taxi route*] **Notes 8, 11, 12**	Read clearance silently Crosscheck Tell PM to accept clearance	Read clearance silently Crosscheck Send: **DM3:** ROGER

Notes and Justifications:
1.) Weather and clearance information is obtained prior to or during cockpit and FMS setup.
2.) When CPDLC and/or ADS-C services are available for the flight, the flight crew should initiate an AFN logon no earlier than **45 minutes** prior to ETD. The Logon address of ATSU is the current ATSU for the flight information region (FIR) that the departure airport is located within. [55]
3.) Obtaining an ATC clearance via **voice** requires that both pilots listen to the clearance. [33]

A.1. TAXI	Preflight Checks at the Gate
4.) Obtaining the clearance via **CPDLC** allows the clearance to be stored and viewed. The request for and acceptance of the route clearance and taxi information should not distract the crew from the cockpit setup, checklist and briefings. [108] 5.) CPDLC use at the gate for Company and ATC communications gives the crew the flexibility to postpone answering the UM until checklists and briefings are complete. It has been shown [47, 106, 3, 108] that interruptions have caused crews to miss important items on a checklist. 6.) The omission of a required action or an inappropriate action is the most frequent causal factor in incidents and accidents [106,3]. These omissions or errors are often the result of an interruption or distraction. Also, [109] reveals that 14% of crew reports include references to an interruption or distraction. 7.) From experience, if the crew wants to make small modifications to the ATC route clearance or change the final altitude, it is much easier to accept the clearance as is, and then request a route modification or altitude change when airborne. 8.) The "graphic D-TAXI" capability enables the provision of taxi route clearances to flight crew in graphical format in addition to text format. The controller does not need to know whether or not the aircraft is D-TAXI graphic capable and so the controller display doesn't distinguish D-TAXI graphic-capable aircraft from non-D-TAXI graphic-capable aircraft. Therefore, ground systems, suitable for graphical D-TAXI route data generate this data along with the textual route data to each aircraft. [20] 9.) A PDC gate hold is most common at busy U.S. airports and may include instructions for the crew to contact a separate gate hold frequency for further information and to monitor any changes. [39] 10.) With parking brake set or during non-critical phases of flight, both pilots should independently read and verify the clearance. FMS or MCP data entry should be cross-checked with both crew members [55, 64, 65] 11.) With parking brake set, both pilots independently read clearance, then verify the clearance with each other. Both pilots review the clearance against the paper chart. Crews enter the taxi clearance into the display system and verify and cross-check. Future AMMs will have the ability to accept data linked taxi clearances and graphically portray them. With such technology, it may be acceptable to receive and respond to a taxi clearance during aircraft movement on the ground. [55, 64, 65] 12.) The limitation of providing the CPDLC taxi clearance during preflight is that the route is likely to change but crews brief on this route. [83]	
Recommendations: 1.) It is recommended that the time-out restriction be extended to at least 10–15 minutes for the crew to load and evaluate the full route clearance. This extended time-out should only be applicable when at the gate or taxiing. 2.) It is recommended that the PIC take advantage of the fact that the route clearance UM does not have to be acted on immediately to help avoid cockpit distractions and interruptions.	

A.2. TAXI	Preflight Briefing	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Pilot Flying performs the briefing. The crew will typically use the FMS as a briefing tool	Briefing to include ground operations and expected taxi route. [33] PIC should consider briefing on how CPDLC will be managed during the flight.	Follows along with the briefing. Voices concerns and questions
Notes and Justifications: 1.) Captains set the tone on the flight deck. Their initial crew introduction and briefing is an important leadership opportunity and they should encourage all crewmembers to provide information about operational issues. [55]		

A.3. TAXI	Before Start Checklist	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Checklist performed prior to pushback.	Calls for Before Start checklist	Read checklist

A.4. TAXI	Clearance for Pushback

A.4. TAXI	Clearance for Pushback	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft is at the gate, doors closed and ready for pushback.	Request FO ask for pushback clearance. Coordinate push back with ground crew.	Verifies door warning lights extinguished. Calls ramp control for pushback clearance, or uses CPDLC for airports without ramp control. **Note 5**
Required CPDLC procedures if not using Ramp Control for pushback. **Note 5**	Verify downlink message is correct. **Note 8**	Send: **DM146**: REQUEST PUSH BACK [*pushback information*] [*assigned time*]
If taxi route is not received prior to pushback or they need an update, crew may want to ask for expected taxi route.	Verify downlink message is correct. **Note 8**	Send: **DM149**: REQUEST TAXI ROUTING INFORMATION
Crew receives: **UM313:** PUSH BACK APPROVED [*pushback information*] [*assigned time*] **Note 5**	Read clearance silently Crosscheck Tell FO to accept clearance	Read clearance silently Crosscheck Send: **DM0:** WILCO

Notes and Justifications:
1.) Each operator develops specific pushback policies and procedures that are tailored to their aircraft and specific operations and approved by the FAA. [19] [11] [64, 65]
2.) Pilots should contact ground control or clearance delivery prior to starting engines as **gate hold procedures** will be in effect whenever departure delays exceed or are anticipated to exceed 15 minutes. The sequence for departure will be maintained in accordance with initial call up unless modified by flow control restrictions. Pilots should monitor the ground control or clearance delivery frequency for engine startup advisories or new proposed start time if the delay changes. [39]
3.) Engine start is coordinated with ground crew using hand signals and intercom in accordance with flight crew operating manual (FCOM). [19]
4.) CPDLC is not considered for airline ramp operations. [19]
5.) Airports **without** ramp control request crew to contact ground control prior to pushback. [39]
6.) Approximately five minutes prior to departure, the ground crew will coordinate the proposed engine start time with the flight crew. At this time, the parking brake should be set and wheel chocks removed. The headset operator is responsible for verifying that all personnel are clear of the aircraft. [19]
7.) After tow tractor and tow bar have been connected and clearance obtained, give push-out signal to tractor operator. Headset operator must accompany tractor and aircraft during push-out to observe for possible safety hazards. Tractor operator is responsible to observe headset operator and aircraft for signals or possible safety hazards. After tractor and tow bar are clear of aircraft, proceed as described in the Taxi-Out Gate procedure. [19]
8.) Normally, CPDLC downlink messages should be reviewed by each applicable flight crew member independently before the message is sent. [55]

A.5. TAXI	After Start Checklist	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
During and/or after pushback, crew performs engine start.	Perform engine start Call for After Start checklist	Read (challenge) checklist

NOTES and JUSTIFICATIONS:
1) Captain may elect to call for taxi, then perform the After Start Checklist during the initial part of the taxi. Although this expedites moving the a/c, it distracts the crew from monitoring traffic and ramp instructions. This technique is also used to avoid blocking other aircraft waiting for pushback.

A.6. TAXI	Ramp Area Taxi	
RECOMMENDATION:	USE VOICE	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
After start checklist is complete and pushback crew has left. Aircraft is ready to taxi to the ATC movement area.	Request FO call for ramp taxi	Call Ramp Control for taxi clearance
Ramp control has issued taxi instructions via voice to a spot just prior to the movement area.	Taxi aircraft as instructed by Ramp Control	Monitor wingtip clearance and ramp traffic. Back-up PIC with ramp taxi information. Handle voice comms with Ramp Control.
Because the aircraft is still connected (logged on) to CPDLC, it is possible the crew will receive an uplink message. If a UM is received while taxiing on a congested ramp, the PIC may elect to wait until he stops before entering movement area to contact Ground Control for taxi clearance.	The PIC will want to know if the UM contains a priority instruction or information such as a gate hold or a runway change requiring a different ramp taxi route from Ramp Control.	If no higher priority exists, read the UM and inform PIC of its content.

Notes and Justifications:
1.) At large airports, airlines control the parking and flow of aircraft in and out of the ramp (**non-movement**) area. The ramp controller will instruct the crew to follow a route from the gate to a position (spot) at the edge of the movement area and to contact Ground Control. [39]
2.) Movement of aircraft or vehicles on **non-movement areas** is the responsibility of the pilot, the aircraft operator, or the airport management. [37]
3.) Airlines that do not have the frequency into an airport to support a ramp control operation are required to use (and pay for) gates and ramp areas controlled by other airlines.

Recommendation:
1.) Voice communications should be used for controlling aircraft movement within the airline's ramp area because of the close quarters, the quickly changing dynamics of the operations, and because the non-movement ramp area is controlled by airline operations personnel—normally in strategically located towers overlooking the ramp areas.

A.7. TAXI	Ground Control Taxi Clearance	
RECOMMENDATION:	USE VOICE	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Voice communications will be used for initiating taxi. [39, 11]	Request FO call Ground Control for taxi.	Calls ATC Ground Control for taxi clearance. Performs proper read back of clearance and all runway hold instructions. [39]

Notes and Justifications:
1.) Because the aircraft is still connected (logged on) to CPDLC, the crew may receive an uplink message.
2.) At airports **without** airline ramp control, the crew will contact **Ground Control** to request taxi instructions after pushback from the gate. [11]
3.) Crew should read back the runway assignment, any clearance to enter a specific runway, and any instruction to hold short of a runway or line up and wait. [39]
3.) The crew previously received "**UM315:** EXPECT TAXI [*taxi route*]" message (Table A.1) during preflight checks. It is possible that the taxi route given by Ground Control is different from the EXPECT [*taxi route*] obtained during preflight checks. Therefore, the crew must be vigilant in understanding the taxi clearance and not rely on the expected [*taxi route*] obtained during the preflight check.
3.) After taxi clearance has been received, the crew will evaluate the assigned runway, takeoff restrictions, and taxi route. If

A.7. TAXI	Ground Control Taxi Clearance
they have any questions or concerns, the flight crew will seek clarification from ATC. [33]	

Recommendation:
1.) It is recommended that all movement area ground operations continue to be controlled by voice communications until surveillance services for flight crews become available, mature and installed on significantly large percentage of the airline fleet. This recommendation is based on the fact that the future taxi surveillance provides tools for flight crews that substantially improve taxi awareness and safety. CPDLC **without** these tools is not an improvement, but a distraction. [88]
2.) The airline interviews show that pilots feel that CPDLC use during ramp taxi operations is a distraction and a possible safety hazard. [64, 65]
3.) A procedure that is ponderous and is perceived to increase workload or interrupt smooth cockpit flow will probably be ignored on the line. Even worse, this effect could spread, since a rejected procedure may lead to a more general distrust of procedures, resulting in non-conformity in other areas. [23, 24]

Future Taxi Surveillance Service for Flight Crews [88]
The surveillance service to augment the flight crew's visual awareness, provides to the flight crews information about:

- Airport moving map display
  - follow the assigned route on the Nav Display and/or HUD
  - The taxi route is presented on the ND map display by a yellow line, which turns green when the FO acknowledges the taxi clearance by pressing the WILCO-button. [83]
- Surface movement alerting function
  - provide an alert to the flight crew in case of possible hazardous situations for the aircraft.
- Traffic display function
  - display and identify movement of aircraft and airport vehicles on aprons, taxiways, and runways
- Conflict detection
  - The conflict detection service to prevent incursions of the own ship in restricted areas, as well as the risk of collision with other traffic (infringement of protection areas).

Future Taxi Surveillance for Ground Controllers [83]
The crew's [taxi route] clearance is also fed into the ATC Ground Control A-SMGCS system to monitor the progress of the aircraft with respect to its cleared route to warn the controller of a route deviation. This system is still in the development stages. [83]

A.8. TAXI	Taxi from Ramp to Active Runway	
RECOMMENDATION:	**USE VOICE**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
ATC taxi clearance is received and understood by the crew. Aircraft is taxiing in movement area to active runway.	Taxi aircraft	Receive and enter final takeoff weights from ACARS. Verify takeoff weights are for assigned runway. Handles ATC communication. Backs-up PIC with taxi route information.

A.8. TAXI	Taxi from Ramp to Active Runway	
Notes and Justifications: 1.) Taxiing involves a constantly evolving set of problem solving and conflict resolutions that many times can only be solved by a human judgment and timely response. 2.) A verbal read back from the pilot is not required for an intersection hold short instruction. [39] 3.) The controller typically sequences the crew behind or between other aircraft; therefore, voice will be required to ensure proper sequencing and spacing. It is not until the crew can use the Taxi-CPDLC Moving Map Display and the Traffic Display function can they sequence themselves into the traffic flow to the active runway. [83] 4.) Both pilots should have the airport diagram out, available, and in use. Crosscheck the heading situation indicator (HSI), airport diagram, and airport signage to confirm aircraft position while taxiing. [33].In the future, the ND moving map should satisfy this requirement. 5.) Pilots are encouraged to monitor the local tower frequency as soon as practical consistent with other ATC requirements. [39, 11] 6.) Several airlines such as KLM, Japan Air (AJX), and Atlas/Polar Air Cargo allow the FO to taxi the aircraft in agreement with SOP. .		
Recommendation: 1.) It is recommended that all movement area ground operations continue to be controlled by voice communications until surveillance services for flight crews become available, mature and installed on significantly large percentage of the airline fleet. This recommendation is based on the fact that the future taxi surveillance provides tools for flight crews that substantially improve taxi awareness and safety. CPDLC **without** these tools is not an improvement, but a distraction. [88] 2.) Recent studies support limited use of CPDLC for ground operations. The TAXI-CPDLC service should support only non-time-critical clearances, i.e. start-up, pushback, taxi, and handover. **Time-critical clearances** like crossing, line-up and take-off are issued via voice radio. [83] 3.) EMMA2 test revealed that TAXI-CPDLC operations with the Cockpit Display of Traffic Information (CDTI) require too much head-down time; this explains the increased workload in the ISA (Instantaneous Self Assessment) measurements. [83]		
Taxi Supplementary Notes: 1.) The following CPDLC scenarios **illustrate/analyze the potential difficulty a crew may have** when receiving CPDLC messages during taxi without the advantage of surveillance service for flight crews. 2.) The procedures described in this table are developed for a crew in a high workload environment. The procedures differ because a higher priority (e.g., taxiing the aircraft) exists and the Captain must rely on the FO to supply timely and helpful information. 3.) Use of voice for Ground Control communications is recommended. 4.) These are **not** recommended procedures, but are for analysis only.		
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Crew receives: **UM333:** HOLD SHORT [*position information*]	Before going head down, the PIC will determine if the intersection that is coming up is xx. If it is and close, the PIC will begin to slow. If not, then the PIC will look down at the UM clearance to verify the name of the hold short intersection.	Report to PIC that the UM is a hold short instruction for intersection xx.
After holding short of intersection xx, the crew would like to know if Ground Control forgot about them.	Verify downlink message correct.	Select downlink message to send: **DM151**: REQUEST TAXI UPDATE [*position information*]
Uplink message received: **UM322**: HOLD POSITION	Verify Hold Position UM. A/C is stopped with breaks set.	Report to PIC that UM is to hold position.
Crew receives while: **UM320:** RUNWAY [*runway*] TAXI [*taxi route*]	Verify UM to continue to taxi and discuss route with FO.	Report to PIC that they are cleared to continue to taxi.

A.8. TAXI	Taxi from Ramp to Active Runway	
Crew receives while taxiing: **UM324:** CAN YOU ACCEPT INTERSECTION [*position information*] FOR RUNWAY [*runway*] **+** **UM328:** [distance ground] AVAILABLE This scenario is a typical request from Ground Control to expedite departures. If the crew can take the intersection takeoff (T/O), then they will takeoff sooner. [39]	Determine if the next intersection is the one to be used for the T/O. If it is, then is it close enough to begin slowing. If not, then go heads down to verify the UM. Discuss with the FO. Tell FO to send DM.	Report to PIC that ATC requests intersection T/O. Check intersection and available T/O distance. Discuss with PIC. If agree to intersection T/O, then send: **DM4**: AFFIRMATIVE If not, then send: **DM5**: NEGATIVE
Crew receives while taxiing: **UM329**: INTERSECTION DEPARTURE [*intersection*] **+** **UM320:** RUNWAY [*runway*] TAXI [*taxi route*]	Verify UM taxi instructions. Tell FO to reply. Verify DM.	Report to PIC of taxi clearance to intersection xx. Select downlink message to send: **DM0**: WILCO

A.9. TAXI	Runway Crossing Instructions	
RECOMMENDATION:	**USE VOICE**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
ATC taxi clearance is received and understood by the crew. Aircraft is taxiing in movement area to active runway.	Taxi aircraft	Call Ground Control to read back the runway crossing instruction.

Notes and Justifications:
1.) ATC is required to obtain a readback from the pilot of all runway hold short instructions. [39, 37] It is still to be determined how this requirement will be met using CPDLC. Pilot readback is a critical procedure for the reduction of runway incursions.
2.) A verbal readback from the pilot is not required for a taxiway intersection hold short instruction. [39, 37]
3.) The EU CPDLC project, EMMA2 [83] uses vice communication for time-critical instructions such as hold short, reroute, return to gate, taxi into position and hold, or cleared for takeoff clearance instructions.

A.10. TAXI	Handoff from Ground Control to Tower	
RECOMMENDATION:	**USE VOICE**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft is approaching the active runway threshold.	Taxi aircraft	Monitor taxi
Ground Control instructs crew to monitor tower frequency.	Taxi aircraft	Replies to Ground Control. Switches to Tower frequency.

Notes and Justifications:
1.) Voice communication will be shifted to time-critical instructions such as hold short, [taxi] reroute, return to gate, taxi into position and hold, or cleared for takeoff clearance instructions. [55]
2.) Prior to the point at which the current ATSU will transfer CPDLC and ADS-C services, the flight crew may receive a response to close any open CPDLC message. [55]
3.) When transferring CPDLC and ADS-C services between FIRs, the flight crew should not need to reinitiate a logon. Under normal circumstances, the current and next ATSUs automatically transfer CPDLC and ADS-C services. The transfer is seamless to the flight crew. [55]

A.11. TAXI	Before Takeoff Checklist	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft is next in line for takeoff.	Taxi aircraft Call for Before T/O checklist	Read (challenge) checklist
Notes and Justifications: 1.) Operator FCOM SOP.		

Taxi Notes

1. Outside vigilance during taxi is the responsibility of both pilots. Prior to the aircraft movement or flap movement, both pilots should verify that the aircraft is clear of all obstacles. [19]
2. If possible, paperwork and other activities should be accomplished while the aircraft is not moving and the parking brake is set. [19]
3. One goal of Taxi-CPDLC is to reduce the amount of voice communication. Voice communication will be shifted to time-critical instructions such as hold short, reroute, return to gate, taxi into position and hold, or cleared for takeoff clearance instructions. [83]
4. Voice communication via radio telephony (R/T) is always back-up. Voice communication should be used if any additional information exchange is necessary or in case of safety, or time critical situations. [83]
5. A commercial multi-functional Cockpit Display of Traffic Information (CDTI) display system manufactured by Funkwerk Avionics, which can be used for visualization of various information as well as maps [83]. In the case of EMMA2 it was modified for displaying the TAXI-CPDLC messages exchange only (Figure 4-1).

Figure 4-1 CDTI: Modified for TAXI-CPDLC use

6. The major advantage of the Taxi-CPDLC is the use of the **ND moving map display** of the taxi route, with the name and location of other traffic, including traffic to follow. [83] The airport moving map display is intended to enhance crew positional awareness while planning taxi routes and while taxiing. Crew should avoid fixation on or distraction by the airport moving map. [11]
7. Study debriefings revealed that TAXI-CPDLC operations with the CDTI require too much head-down time; this explains the increased workload in the ISA measurements. [83]
8. The limitation of providing the CPDLC taxi clearance during preflight is that the route is likely to change and crews brief on this route. [83]

4.2.5.2. Takeoff

B.1. TAKEOFF	**Line Up and Wait**	
RECOMMENDATION:	**USE VOICE**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Tower clears crew to line up and wait on Runway xx.	Calls "Below the line" to finish the Before T/O checklist	Reply via voice to line up and wait on Runway xx. Read the last part of the Before T/O checklist.
1.) The tower controller will consider that pilots of turbine-powered aircraft are ready for takeoff when they reach the runway or warm-up block unless advised otherwise. [39] 2.) Tower will either clear the crew for immediate takeoff or to "Line up and wait." [39]		
B.2. TAKEOFF	**Takeoff Clearance**	
RECOMMENDATION:	**USE VOICE**	
Tower clears crew for takeoff on Runway xx.	Begins Takeoff	Reply via voice for cleared for T/O.
1.) Tower will either clear the crew for immediate takeoff or to "Line up and wait" [39]		
B.3. TAKEOFF	**Takeoff**	
End of runway xx	Advances throttle and/or press TOGA. Verify: * correct thrust set * airspeeds	Monitor: * A/P and A/T annun. * Engine indication * Airspeed Callouts: * Call V1, VR * Raise gear
Notes: 1.) Typical SOP T/O callouts. 2.) If FO is the PF, then the PIC will have his hand on the throttles for possible RTO. [19] 3.) Standard noise abatement takeoff profile (ICAO Procedure B) [19]		
B.4. TAKEOFF	**400 to 800 ft AGL**	
400 to 800' climbing, runway heading	Call for desired AFDS (autopilot flight director system) Roll Mode	Select Roll Mode, Verify
1. PF will call for either HDG SEL or LNAV		
B.5. TAKEOFF	**Initial Turn**	
Climbing	Calls for AFDS Heading Mode	Select heading bug to new heading
1.) Start initial turn when > 400 ft AGL [19]		
B.6. TAKEOFF	**Flap Retraction Schedule**	
Flap retract altitude	Call for next flap setting	Select flap setting
1.) Reduce pitch to accelerate and retract flaps on speed schedule		
B.7. TAKEOFF	**Set Climb Power**	
Climbing	Call for climb power	Select climb power
1.) PF will call for : N1 or VNAV on MCP		
B.8. TAKEOFF	**Engage Autopilot**	
Climbing	Call for A/P	Select desired pitch and roll modes
1.) Typically engage A/P > 1000 ft AGL. 2.) The appropriate time for engaging LNAV is at the PF's discretion.		
B.9. TAKEOFF	**After Takeoff Checklist**	
Climbing	Call for After T/O checklist	Performs After T/O checklist
1.) Many airlines perform as a silent checklist by the PM. 2.) Do not allow checklist to interfere with outside vigilance. [19]		

4.2.5.3. Climb

C.1. CLIMB	Handoff from Tower to Departure Control via Voice	
RECOMMENDATION:	**USE VOICE**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft is climbing. Instructs crew to contact Departure Control on frequency xxx.xx.	Fly the takeoff profile.	Acknowledges Tower Selects Departure frequency. Contacts Departure Control
Notes and Justifications: 1.) Tower typically instructs the crew to contact Departure Control at about 1000 feet AGL. 2.) After contacting Departure Control, the crew will usually be instructed to climb to an initial altitude and route.		

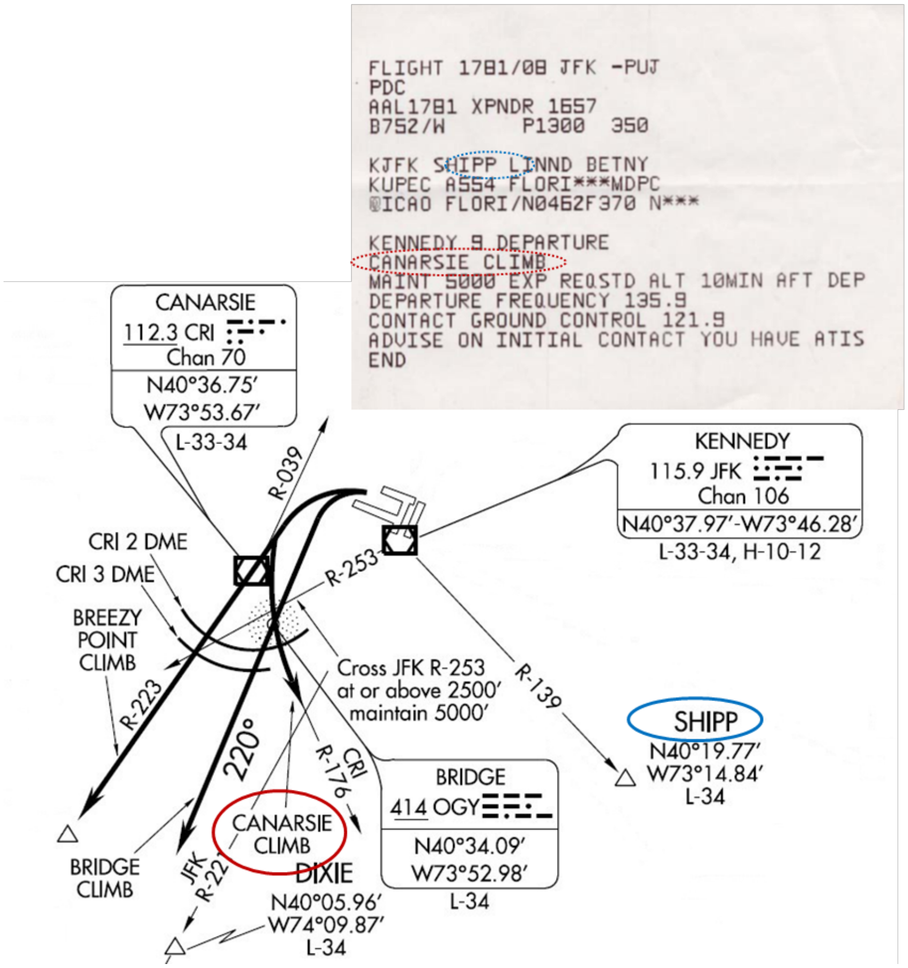
C.2. CLIMB	CPDLC Altitude	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft is climbing through a predetermined "Data Link Altitude".	Flying the SID.	Monitor the climb. Calls out "Data Link Altitude".
Crew receives: **UM285**: CURRENT DATA AUTHORITY [*unitName*] + **UM340**: LATENCY TIME VALUE [*latency value*]	Read UM silently. Verify that Departure Control is the CDA.	Read UM silently. Verify that Departure Control is the CDA. **Note 3**
Notes and Justifications: 1.) Data Link Altitude should be identified in the SID. (Recommendation) 2.) Considerable hand-shaking protocol is used to transfer the crew from the CDA to the NDA. Most of the protocol is invisible to the crew, but several displayed uplink messages could become distractions to the crew during departure. [21] 3.) Response type for **UM285** and **UM340** = N. [21] 4.) The flight crew should promptly respond to CPDLC uplinks to minimize the risk of an open CPDLC uplink message when transferring to the next ATSU. [55]		
Recommendations: **1.)** A "Data Link Altitude" is a **RECOMMENDED** standardized altitude that ATC will use CPDLC as the primary means of communication. Before Data Link Altitude all communication is by voice, after Data Link Altitude the primary communication is CPDLC. (See DATA LINK ALTITUDE Supplementary Notes)		

C.2. Data Link Altitude supplementary notes:
Tower "hands off" the crew to Departure Control via **voice** at about 1000 feet AGL, but the crew is still configuring the aircraft, configuring the auto flight control system (AFCS), and flying the SID route. The discussion below makes the point an altitude should be predefined for when the crew can expect to transfer from voice to CPDLC; the crew receives an uplink message at that altitude confirming that CPDLC is the primary mode of communication with ATC.

The discussion below uses the KENNEDY NINE SID (see Figure 4-2) to illustrate the crew workload during departure. During the early part of this departure, the crew performs the tasks outlined in Table B TAKEOFF, as well as navigating the SID.

During preflight checks (Table A.1.), the crew receives the ACARS Pre-Departure Clearance to fly the KENNEDY NINE Departure, CARARSIE Climb, maintain 5000 ft, expect requested altitude 10 minutes after departure. When established on the CRI R-176 radial, Departure Control will instruct the crew to fly direct to SHIPP intersection and resume own navigation and clear them to a higher altitude.

ACARS Pre-Departure Clearance (PDC) Example:



```
FLIGHT 1781/08 JFK -PUJ
PDC
AAL1781 XPNDR 1657
B752/W       P1300  350

KJFK SHIPP LINND BETNY
KUPEC A554 FLORI***MDPC
@ICAO FLORI/N0462F370 N***

KENNEDY 9 DEPARTURE
CANARSIE CLIMB
MAINT 5000 EXP REQSTD ALT 10MIN AFT DEP
DEPARTURE FREQUENCY 135.9
CONTACT GROUND CONTROL 121.9
ADVISE ON INITIAL CONTACT YOU HAVE ATIS
END
```


Figure 4-2 Kennedy Nine Standard Instrument Departure (Sid)

For this example, the crew will take off on **RUNWAY 31L**, then fly the **KENNEDY NINE DEPARTURE, CANARSIE CLIMB TRANSITION**. The SID instruction for this departure transition is:

CARNASIE CLIMB: Climbing left turn direct CRI VOR/DME, make turn east of CRI R-039, then via CRI R-176. Cross CRI 2 DME or JFK at or above 2,500 feet, maintain 5,000 feet. Thence, via vectors to assigned route/fix. Expect clearance to filed altitude/flight level ten minutes after departure.

CPDLC During Departure

For flying this SID, a myriad of considerations, decisions, and actions are required even during **good** weather. When the crew is flying a typical departure such as the JFK9 CARNASIE CLIMB, the tower or departure control may send a CPDLC UM that it would create an unwanted distraction and interruption below 10,000 feet. Certainly both pilots should **not** go "heads down" to independently read the UM as recommended by some research. In a research survey [107] it was found that all three surveyed carriers trained CPDLC message evaluation as a two-person procedure that involves one pilot reading the message aloud, either from the MCDU or from a printout. 96% of pilots felt their company's procedure was adequate for crew coordination and for understanding the clearance.

The NASA ASRS report examples show how easy it is to have a procedural deviation from a published departure:

- **ASRS #705503**. I completed the takeoff from runway 31L. Speed mode was selected after takeoff. At 400 ft AGL; I started a left turn direct CRI. The course needle was centered to CRI and navigation mode selected. We turned within 4.0 DME of JFK using a distance ring on the fix function at the FMS. With wind correction I was flying approximately 230-235 degree heading direct CRI. As soon as VOR #1 went into 'DR' mode (with DR on the FMA); I held my heading anticipating station passage and asked the first officer to dial 176 degree radial on the VOR #1 course knob. As the first officer was dialing the 176 degree radial; New York Departure told us to turn immediately to a 180 degree heading to avoid LGA airspace.
- **ASRS #686337**. Departing JFK on the JFK 9 CARNASIE climb. PF was first officer. Took off; turned left to the CRI VOR. On check-in with departure; level-off altitude was changed from 5000 ft to 4000 ft. The crew cleaned up the aircraft on schedule. The PF called for speed intervene of 250 KTS. PM selected a heading to intercept the CRI 176 degree radial prior to reaching the CRI VOR (VHF omnidirectional range). PF began a left turn while leveling at 4000 ft. The aircraft crossed the CRI VOR in the turn. While rolling out on a heading to intercept the 176 degree radial; departure called and asked which departure we were doing. The PM responded that we were on the JFK 9 CARNASIE. Departure responded with '*not even close*!'

It is recommended that frequency change from tower to TRACON be made via voice only. It is recommended that ATC Communication Management (ACM) transfer from T-ATSU (Tower) to R-ATSU (TRACON) where both ATSUs are CPDLC equipped to use voice frequency change instruction independent from data communications transfer operating method and diagram. This procedure is described in the CPDLC Safety and Performance Requirements (SPR, Section 5.1.1.3.2.2) [21]. Creating a controller/pilot SOP to change the Current Data Authority (CDA) from tower to departure at 10,000 feet would allow the crew to anticipate the uplink message and reduce the distraction/interruption at low altitudes and high workload.

When the voice frequency transfer is independent of the CPDLC communications transfer, then the timing of the data communications transfer is locally determined. [21] The R-ATSU **system** (not the controller) sends **UM285:** CURRENT DATA AUTHORITY [*unitName*] and **UM340:** LATENCY TIME VALUE [*latency value*] uplink messages. If applicable **UM233:** USE OF LOGICAL ACKNOWLEDGEMENT PROHIBITED is also sent. It is these messages, the CPDLC transfer procedure and the unnecessary distraction they create that should be delayed to the "Data Link Altitude."

C.3. CLIMB	**Out of 10,000 feet**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft climbs through 10,000 feet MSL (mean sea level).	Acknowledge "Out of 10"	Calls "Out of 10" Selects landing lights off. Makes PA announcement.

C.4 CLIMB	**Handoff from Departure Control to Center**	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
R-ATSU (Center) sends: **UM160:** NEXT DATA AUTHORITY [*facility*] sent by the NDA **system**. When CPDLC is successfully established between the aircraft and the R-ATSU, the next data authority identification is displayed to the flight crew.	Read UM silently. Verify that Center is the NDA.	Read UM silently. Verify that Center is the NDA.

C.4 CLIMB	Handoff from Departure Control to Center	
T-ATSU (Departure Control) sends: **UM117:** CONTACT [*unitName*] [*frequency*]. Note 3	Read UM silently. Evaluate and discuss. Tell PM to send WILCO.	Read UM silently. Evaluate and discuss. Send: **DM0:** WILCO. Set the specified frequency and contact the R-ATSU (Center) controller by voice. **Note 4**
R-ATSU (Center) system sends: **UM285**: CURRENT DATA AUTHORITY [*unitName*] + **UM340**: LATENCY TIME VALUE [*latency value*]	Read UM silently. Verify that Center is the CDA.	Read UM silently. Verify that Center is the CDA. **Note 5** **Note 7**

Notes and Justifications:
1.) Starting approximately 10 minutes prior to the FIR boundary, the PM should look for a successful transfer from the current ATSU to the next ATSU by observing the change in the active center indication provided by the aircraft system. [55]
2.) Before sending the transfer instruction, when there are open uplink messages, and when a CPDLC voice frequency change instruction is initiated, the controller is notified of any open uplink messages. The T-ATSU system/controller either:

- Waits for the responses to the open uplink messages and then continues with the transfer instructions, or
- Resolves the open uplink messages (e.g., via voice instructions) and then continues with the transfer instructions [55].

3.) The T-ATSU could also send:

- **UM118**: AT [*position*] CONTACT [*unitName*] [*frequency*]
- **UM275**: AT [*time*] CONTACT [*unitName*] [*frequency*]

4.) The T-ATSU could also instruct the crew to **monitor** the frequency instead of contact.
5.) Response type for **UM160**, **UM285** and **UM340** = N.
6.) The flight crew should promptly respond to CPDLC uplinks to minimize the risk of an open CPDLC uplink message when transferring to the next ATSU. [55]
7.) Since the transfer of communications at FIR boundaries is not explicitly indicated to the receiving ATSU, the only way to confirm that it has taken place is for the aircraft and ATSU to exchange a CPDLC message. [55]
8.) Each time a connection is established, the flight crew should ensure the identifier displayed on the aircraft system matches the logon address for the controlling authority. [55]
9.) R-ATSU = Receiving Air Traffic Service Unit → in this case is Center (ARTCC)
T-ATSU = Transferring Air Traffic Service Unit → in this case is Departure Control (TRACON)

C.5. CLIMB	Transition Altitude	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C climbs through transition altitude	Set and crosscheck the altimeters to standard	Call out: "____FEET ____SET" [19] Set and crosscheck the altimeters to standard

C.6. CLIMB	Intermediate Level-Off Altitude/FL	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C climbing to assigned altitude/FL.	Check automation mode. Monitor the automation has captured the level-off altitude.	Monitor the automation.
Crew receives: **UM219:** STOP CLIMB AT [*level*]	Read UM silently. Evaluate and discuss. Set altitude in the MCP alt window. Crosscheck. Tell PM to **ACCEPT** the clearance. Monitor last 1000'.	Read UM silently. Evaluate and discuss. - Crosscheck. Send: **DM0:** WILCO. Monitor last 1000'. Make 1000' altitude call out.

C.6. CLIMB	Intermediate Level-Off Altitude/FL

Notes and Justifications:
1.) ATC instructs crew to stop the climb below the previously assigned level.
2.) It is very rare that the crew will reject a level-off clearance in a climb.
3.) The altitude alerting system shall be used during all phases of flight to assist the flight crew in altitude awareness and to prevent deviation from assigned clearances. During climb, the flight crew shall set the next clearance altitude in the altitude selector window.

- With the autopilot ON, the PF will set the new clearance altitude in the altitude selector window.
- With the autopilot OFF the PM will set the new clearance altitudes in the altitude selector window.
- Both pilots will verbally and visually acknowledge the cleared altitude set in the altitude selector window. [19]

3.) The purpose of reporting intermediate levels should be served by ADS-C. [55]

C.7. CLIMB	AOC Communication	
RECOMMENDATION:	USE CPDLC	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Crew must send departure message to company via ARINC or voice. **Note 1**	Acknowledge to monitor ATC comms. Switch from LEGS page to CPDLC Comm page.	The duty to monitor ATC comms is passed to the PF. The PM states "*you have ATC comms, I'm talking to company*" After comms with AOC, the PM states that he has **ATC** comms.
Crew receives: **Any UM**	The PF may wait until the PM is done, or may reply to ATC. This decision should be the judgment of the PF. When the PM has completed AOC Comms, the PF will brief the PM on the status of a UM and the response and actions taken.	N/A

Notes and Justifications:
1.) When communicating with company via voice or ACARS, the pilot (PF or PM) is essentially "out of the loop" with the other crewmember and ATC. Therefore, a prescribed handoff occurs between the pilots that when one is "off line" talking to company, the other has the ATC comms.

Climb Notes:
Flight deck workload, autopilot status, communications requirements, etc. can all influence which pilot should perform certain functions at any given time. [19]

4.2.5.4. Cruise

D.1. CRUISE	Cruise Step Climb	
RECOMMENDATION:	USE CPDLC	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C is level at assigned cruise flight level		
Crew receives: **UM20:** CLIMB TO [*level*]	Read UM silently. Evaluate and Discuss. If acceptable, set up FMS/MCP. Crosscheck Tell PM to accept the clearance. Monitor last 1000'	Read UM silently. Evaluate and Discuss. - Crosscheck. Send: **DM0:** WILCO. Monitor last 1000'. Make 1000' altitude call out.
Notes and Justifications: 1. If the new altitude is above the cruise altitude set in the FMS CRUISE page, then change the FMS cruise altitude to the new altitude.		

D.2. CRUISE	Passenger Announcement	
RECOMMENDATION:	USE CPDLC	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Crew workload is low.	Captain is making a passenger announcement.	
Crew receives: **Any UM**	**Note 1, 2**	The FO will use judgment on how to handle the UM. The FO will brief the Captain on the status of a UM and the response and actions taken by the FO.
Notes and Justifications: 1.) If the Captain is the PF, then PF duties are assigned to PM while the Captain makes the announcement. If the Captain is the PM, then the PF will assume PM duties. 2.) Traditionally the Captain makes the passenger announcement. If the Captain delegates the task of making the passenger announcement, then the above roles are reversed. 3.) An advantage of CPDLC is that ATC comms will not disrupt an announcement. It could be startling to passengers when a Captain stops talking in mid-sentence.		

D.3. CRUISE	Navigation	
RECOMMENDATION:	USE CPDLC	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C is at assigned flight level and on route.		
Crew receives: **UM77:** AT [*position*] PROCEED DIRECT TO [*position*]	Read UM silently. - Evaluate and discuss. If acceptable, set up FMS/MCP. Crosscheck. EXECUTE. Tell PM to accept clearance.	Read UM silently. If loadable, load UM into FMS. Evaluate and discuss. - Crosscheck. - Send: **DM0:** WILCO.
Notes and Justifications: 1.) "Fix to Fix" direct navigation should be requested and utilized whenever possible. This, combined with the use of FMC ECON CRUISE, will result in the most economical cruise profile. While at cruise, both Nav Radios should be operated in the AUTO position to allow FMC radio updating. Substantial deviations from flight planned altitudes or airspeeds due to weather,		

D.3. CRUISE	Navigation
ATC, etc. should be analyzed with a combination of computer information, conventional fuel planning, buffet boundaries, etc. [19]	

D.4. CRUISE	Out of Sequence Messages	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Sequence of pilot requests and ATC clearances. **Note 3**	PF wants step climb based on the computer flight plan and aircraft performance.	Monitoring / using CPDLC
N/A	Request higher altitude from PM. Verify DM.	Send: **DM53:** WHEN CAN WE EXPECT HIGHER
Crew receives concatenated UM: **UM6:** EXPECT [FL380] + **UM245:** EXPECT CLIMB [*timesec*] (3 minutes)	Read UM silently. Evaluate and discuss. Because FL380 is too high, tell PM to **REJECT** clearance.	Read UM silently. Evaluate and discuss. **Reject** clearance by sending: **DM0:** UNABLE + **DM66**: DUE TO AIRCRAFT PERFORMANCE
Note 4	Tell PM to request FL340. Verify DM.	Send: **DM9:** REQUEST CLIMB TO [FL340] + **DM66**: DUE TO AIRCRAFT PERFORMANCE
Crew receives: **UM20:** CLIMB TO [FL380]	Read UM silently. Evaluate and discuss. Tell PM to **REJECT** clearance.	Read UM silently. Evaluate and discuss. **Reject** clearance by sending: **DM0:** UNABLE
Crew receives: **UM20:** CLIMB TO [FL340]	Read UM silently. - Evaluate and discuss. If acceptable, set up FMS/MCP. Crosscheck. EXECUTE. Tell PM to **ACCEPT** clearance	Read UM silently. If loadable, load UM into FMS. Evaluate and discuss. - Crosscheck. - Send: **DM0:** WILCO

Notes and Justifications:

1.) ATC may accept the sequence of requests and responds with a clearance to each request that the crew did not expect. The flight crew will detect that the clearance sequence is inconsistent with the requests. [20, Sect B.4.6]

2.) In the worst case, the flight crew does not detect that the clearance is inconsistent with the request and starts executing the clearance. [9, Sect B.4.6]

3.) This scenario was developed for a recent research project for CPDLC menu and procedure design. [54]

4.) The scenario was timed such that the two CLIMB requests from pilot (DM9) and ATC (UM20) crossed each other simultaneously. [54, Sect 3.3.7]

5.) From the research paper, all four pilots correctly assessed the out-of-sequence clearance and made an appropriate decision to respond with an UNABLE. All four pilots indicated that they would not require voice to resolve an out-of-sequence situation. [54, Sect 3.3.7]

6.) To avoid potential ambiguity, the flight crew should not send multiple clearance requests in a single downlink message. [55, 21]

7.) The flight crew should check the correctness and the appropriateness of every message before sending it. [21]

D.4. CRUISE	Out of Sequence Messages
Recommendations: 1.) It is recommended that the crew use voice if they have any uncertainty or misunderstanding about the clearance. In fact, the EUROCONTROL CPDLC procedures manual. Sect 5.5 [31] states: "*If uncertainty arises to either controllers or aircrew, about the content of a data link message, the application of a data link message, or the validity of a data link message, they must REVERT TO VOICE to clarify the situation*."	

D.5. CRUISE	Large Clearance Reroute	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
	Enter the route into the FMS	Check the FMS
Crew receives large route clearance: **UM337:** CLEARANCE LIMIT [*position*] + **UM267:** CLEARED TO [*route clearance enhanced*] + **UM74:** PROCEED DIRECT TO [*position*]	Read UM silently. - Consider sending **STANDBY**. Evaluate and discuss. If acceptable, then set up FMS/MCP Crosscheck. EXECUTE. Tell PM to **ACCEPT** clearance.	Read UM silently. If loadable, load UM into FMS. - Evaluate and discuss. - Crosscheck. - Send: **DM0:** WILCO

Notes and Justifications:

1.) Seamless integration of CPDLC procedures with current FMS/Automation procedures is significant for crew information management and cockpit discipline necessary for safe and effective transition to the NextGen environment. A recent Flight Safety Foundation study identified critical pilot errors when making route changes in the FMS: [5]

- Pilots reprogram the FMS with a new lateral route and fail to notice that the disruption to navigation information has caused the automation to revert to HDG (heading) mode. [5]
- Pilots fail to ensure the FMS has the correct departure, en route, or arrival route programmed.
- Pilots receive a new routing from ATC and subsequently fail to ensure the FMS has activated the correct waypoint
- Pilots fail to program the correct altitude and speed crossing restrictions in the FMS.
- Pilots enter a direct-to routine and fail to ensure that the aircraft is proceeding to the correct waypoint.
- Pilots fail to confirm that the selected arrival or departure procedure waypoint and/or restrictions match the charted produce.

2.) **UM337** CLEARANCE LIMIT [*position*] shall be sent concatenated with only one of the following message elements: **UM266**, **UM267**, and **UM268**, denoting the route clearance to be limited. [21]

3.) **UM267** will replace all parts of the current active route in an aircraft system capable of auto-loading route uplinks. Therefore **UM267** should be used only when diverting to an alternate airport or when the entire route to the destination airport is to be changed. It can be used for partial revisions to the route only if the unchanged downstream parts of the route are also included in the route clearance. [21]

4.) To remove any potential for ambiguity in how the aircraft should proceed from its present position to intercept or link to the route clearance enhanced field, the clearance should include an **unambiguous intercept point** for the aircraft to acquire the route in the route clearance uplink (e.g., by a direct to a waypoint in the route clearance enhanced field.) [21]

5.) If the route clearance is passed in **UM266** or **UM267**, the aircraft system will overwrite any other data already processed in that uplink with the contents of the received UM266 or **UM267**. For this reason, **UM74** (or equivalent) follows the UM266 or **UM267** so that **UM74** (or equivalent) can be retained by the aircraft. [21]

6.) The intercept point will appear after the route clearance enhanced field, **not in front as expected by the crew**. [21]

D.6. CRUISE	Negotiation for Large Reroute	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
The new route issued by ATC is not acceptable to the crew.		

D.6. CRUISE	Negotiation for Large Reroute	
Crew receives large route clearance: **UM337:** CLEARANCE LIMIT [*position*] + **UM267:** CLEARED TO [*route clearance enhanced*] + **UM74:** PROCEED DIRECT TO [*position*]	Read UM silently. - Consider sending **STANDBY**. Evaluate and discuss. If the clearance is not acceptable, then tell PM to **REJECT** the clearance.	Read UM silently. If loadable, load UM into FMS. - Evaluate and discuss. - Reject clearance by sending: **DM1:** UNABLE

Notes and Justifications:

1.) If the flight crew either:

- Does not receive a controller response to an open CPDLC downlink message within a reasonable time period and no error message has been received indicating that the message was not delivered; or
- Receives a STANDBY message in response to an open CPDLC downlink message but does not receive a closure response within a reasonable period of time, e.g. 5 minutes

Then, the flight crew should send a query using one of the **Negotiation Requests** messages or a [free text] message rather than resending the clearance request message. [55]

2.) If the intent of an uplinked message is uncertain, the flight crew should reject (UNABLE) the message. The flight crew may use either CPDLC or voice to confirm the intent of the message. [55]

3.) Voice should be used as the backup communication medium. [55]

D.7. CRUISE	Conditional Clearance	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Below are five independent clearance scenarios:		
Crew receives concatenated message: **UM19:** MAINTAIN [level] **Note 2** + **UM248:**AT [*timesec*] CLIMB TO [*level*] The crew will monitor the **time** to comply with the clearance. **Note 4.** Controller concatenated **UM19** with **UM248**. **Notes 2 and 3.**	Read UM silently. Evaluate and discuss. If acceptable, then set up FMS/MCP. Crosscheck. Tell PM to **ACCEPT** clearance.	Read UM silently. Evaluate and discuss. - Crosscheck. Send: **DM0:** WILCO This time conditional clearance is **not** loadable into the FMS.
Crew receives: **UM310:**AT [*level*] MAINTAIN [*speed*] This UM will likely be concatenated after a "CLIMB TO" or "DESCEND TO" UM. The crew will monitor the **level** to comply with the speed clearance. **Note 3.**	Read UM silently. Evaluate and discuss. If acceptable, then set up FMS/MCP. Crosscheck. EXECUTE. Tell PM to **ACCEPT** clearance.	Read UM silently. Evaluate and discuss. - Crosscheck. - Send: **DM0:** WILCO This altitude conditional clearance is **not** loadable into the FMS.

D.7. CRUISE	**Conditional Clearance**	
Crew receives: **UM188:** AFTER PASSING [*position*] MAINTAIN [*speed*] Note that this conditional clearance uses the phrase "AFTER PASSING" instead of "AT". It is the only UM that uses "AFTER PASSING". FMS VNAV speed constraints entered in the LEGS Page are not valid during cruise.	Read UM silently. Evaluate and discuss. If acceptable, then set up FMS/MCP. Crosscheck. Tell PM to **ACCEPT** clearance. Cannot modify the flight plan because speed changes are not allowed in the LEGS page during cruise. **Note 5**	Read UM silently. Evaluate and discuss. - Crosscheck. Send: **DM0:** WILCO This position conditional clearance during cruise is **not** loadable into the FMS.
Crew receives: **UM077:**AT [*position*] PROCEED DIRECT TO [*position*]	Read UM silently. - Evaluate and discuss. If acceptable, then set up FMS/MCP Crosscheck. EXECUTE. Tell PM to **ACCEPT** clearance.	Read UM silently. Load UM into FMS **Note 8** Evaluate and discuss. - Crosscheck. - Send: **DM0:** WILCO
Crew receives concatenated conditional message: **UM 20:** CLIMB TO AND MAINTAIN FL330 + **UM 78:** AT FL330 PROCEED DIRECT TO TUNTO + **UM 129:** REPORT LEVEL FL330.	Read UM silently. Evaluate and discuss. If acceptable, then set up FMS/MCP. Crosscheck. Tell PM to **ACCEPT** clearance.	Read UM silently. Evaluate and discuss. - Crosscheck. Send: **DM0:** WILCO **Note 7**

Notes and Justifications:

1.) For many years, conditional clearances have been identified as a prominent problem in both voice and CPDLC communications. [107]

2.) The crew must recognize the conditional clearance. Several interface and procedural changes have been introduced to address this problem. Changes include adding “**maintain FLxxx**” to the clearance text proceeding the “**at**” restriction and changing text formatting conventions used in flight deck presentation of uplink messages [14].

3.) The controller should precede conditional vertical clearances containing the word “**AT**” with **UM 19** MAINTAIN [*level*] indicating to the flight crew to maintain their present level/altitude until the condition of the clearance is satisfied. [55]

4.) Many conditional clearances cannot be programmed directly into the FMS, e.g., "AT [*time*] or [*level*] PROCEDE DIRECT TO [*position*] ." The newer generation FMS on the 777 and 787 displays a prompt on the MDF to remind the crew of the condition.

5.) A LEGS page waypoint speed constraint in **VNAV Mode** is interpreted as a “cannot exceed” speed limit, which applies at the waypoint and all waypoints preceding the waypoint if the waypoint is in the **climb** phase or all waypoints after it if the waypoint is in the **descent** phase.

6.) Procedures or techniques should help mitigate the potential that crew may forget a conditional clearance. Crews have used creative techniques such as putting a coffee cup over the flap handle to use as a memory jog or a 'post-it' reminder on the yoke to" monitor" a position, time, or level condition. Part of the crew discussion on how they plan to avoid missing the time, position, or altitude condition.

7.) Crew will need to remember to proceed direct to TUNTO and to report level FL330.

8.) This position conditional clearance is loadable into the FMS, or the "AT [*position*]" is, or can be entered as a waypoint.

D.8. CRUISE	**RTA Clearance**	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Crew receives: **UM252:** CROSS [*position*] AT [*RTAtimesec*]	Read UM silently. - Evaluate and discuss. Consider sending **STANDBY**. If acceptable, then set up FMS/MCP Crosscheck. EXECUTE. Tell PM to **ACCEPT** clearance.	Read UM silently. Load UM into FMS. Evaluate and discuss. - - Crosscheck. - Send: **DM0:** WILCO

Notes and Justifications:
1.) The "RTA timesec" parameter consists of an arrival time plus an optional "RTAsec Tolerance" parameter that provides the plus/minus arrival time tolerance in seconds. [21]
2.) RTA waypoints are valuable for approach sequencing, but seldom used in the current flight plan-based ATC operations. Research [75] has demonstrated the current generation avionics can achieve time control with 4-second accuracy at the Initial Approach Fix. The same research showed that using aircraft descent and approach spacing of 105 seconds or greater should not cause separation problems. [75]
3.) The current FMS only adjusts speed during **cruise** to meet the RTA time restriction, not during climb or descent. But the FMS is still capable of the demonstrated RTA accuracy at the FAF [75] using the FMS calculated descent profile. To do this, ATC should refrain from speed constraints, altitude constraints, or vectoring during descent and approach.
4.) Crew should maintain updated wind information in the FMS for RTA operations.
5.) It is typical for the crew to take extra time in responding to an RTA clearance due to the infrequent use of the clearance and the crew unfamiliarity of the RTA feature.
6.) The simulations showed that it took about 40 seconds for the a/c to accelerate from ECON to the RTA required Mach. There may be some delay before the crew knows if the a/c can make the RTA restriction.
7.) Operational response times may vary depending on workload and complexity of the instruction or clearance. [55] **DM2:** STANDBY may be useful for taking the necessary time to properly evaluate all the requirements to meet the RTA time constraint. Evaluation includes loading latest wind data, computing cruise altitude step climb requirements, possible weather deviations, and assessing the speed necessary to meet the RTA time constraint.

D.9. CRUISE	**Crewmember Leaves the Cockpit**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
The PF must leave the cockpit.	Briefs the PM on the current state and anything to expect.	Follows brief by PF
Crew receives: **Any UM**	N/A	CPDLC comms will be performed by the remaining flight crewmember. PM will brief the PF upon return to flight deck.

Notes and Justifications:
1.) When one of the pilots leaves the cockpit, the other pilot assumes the duties. If the PF is to leave the cockpit, then the PM is briefed by the PF on current conditions and clearance, as well as what can be expected.
If the PM is to leave, then the PF will monitor ATC comms.
The returning crewmember is briefed on any changes.
2.) Cockpit security is clearly defined in the company's flight operations manual. Many flight departments require another crewmember (another pilot if it is an augmented crew, or a Flight Attendant if not) be in the cockpit when the PF or the PM leaves the cockpit.
3.) The Captain will typically brief the FO when leaving the cockpit. This briefing provides guidelines and limits on what the FO can accept for a clearance and what decisions must wait until the Captain returns.

D.10. CRUISE	**Weather Deviations**	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
The crew must deviate around some thunderstorms along the route.		
N/A	Request PM for weather deviation with direction and distance info. Verify DM. **Note 1, 5**	Compute/verify the direction and distance parameters. Send DM request: **Note 2** **DM27:** REQUEST WEATHER DEVIATION UP TO [*specified distance*] [*direction*] OF ROUTE
Crew receives concatenated message: **UM82:** CLEARED TO DEVIATE UP TO [*specified distance*] [*direction*] OR ROUTE + **UM75:** WHEN ABLE PROCEED DIRECT TO [*position*]	Read UM silently. Evaluate and discuss. If acceptable, then set up MCP/FMS. Crosscheck. Tell PM to **ACCEPT** clearance.	Read UM silently. Evaluate and discuss. - Crosscheck. Send: **DM0:** WILCO

Notes and Justifications:

1.) Weather deviations are almost always initiated by the crew to go left or right of thunderstorms or large cumulus built-ups. Using R/T voice comms, the crew will typically ask for 10, 20, or even 30 degrees left or right of course for a given number of miles. The crew uses the radar range rings to estimate the number of miles to remain on the requested heading to get around the weather. This is the easiest technique to request weather deviation. Therefore, the PF may request deviation from the PM using this "heading/distance" technique and have the PM compute the Direction and Off-track distance parameters to enter into DM27. Or, the PF may provide the direction and off-track distance parameter to the PM.

2.) There are two DMs for requesting weather route deviation:

- **DM27:** REQUEST WEATHER DEVIATION UP TO [*specified distance*] [*direction*] OF ROUTE
- **DM122:** REQUEST WEATHER DEVIATION TO [*position*] VIA [*route clearance enhanced*]

The crew should use these two DMs to convey to ATC a pressing need for **weather** deviation. Example ASRS reports [#700557 & #594166] require the use of Captain's emergency authority to deviate around thunderstorms.

3.) The crew should not hesitate to use voice if there is not a timely response to a weather deviation request. CPDLC technology should not contribute to an emergency.

4.) After deviation around weather, the crew will typically want to proceed direct to the next waypoint or a waypoint further down the route, rather than return to the original track.

5.) CPDLC downlink messages should typically be independently reviewed by each applicable flight crew member before the message is sent. [55]

D.11. CRUISE	**Crew Meals**	
Sequence of Events	**Pilot Flying/Monitoring**	**Pilot Eating**
Cruise flight, low workload	Acknowledge having both flying and monitoring duties.	Transfer duties to the other pilot.
Crew receives: **Any UM**	Read UM. Evaluate and discuss. If acceptable, then set up MCP/FMS. Tell PM to **ACCEPT** clearance.	Although one pilot is eating, it is expected that he is monitoring the state of the flight and the CPDLC. The PF still expects input in message discussion and evaluation.

Notes and Justifications:

1.) Before a pilot begins a crew meal, state that the other pilot has his duties, assuming this is non-augmented two-man crew.

2.) Because eating crew meals can be a big distraction in the cockpit, flight departments define specific restrictions in eating the crew meal. SOPs require that only one pilot eat at a time, while the other pilot is flying/monitoring the aircraft. Flights with augmented crews can allow the pilot to eat in the cabin or crew rest area.

3.) In the ATC voice environment, the pilot not eating handles the radio. The pilot eating the crew meal is still monitoring the

D.11. CRUISE	Crew Meals	
state of the flight and listening to ATC. Therefore, the pilot eating is still very much "in the loop." It is the same for CPDLC, the pilot eating is simply not typing, but still monitoring.		

D.12. CRUISE	D-ATIS	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C is within range to receive ATIS		
D-ATIS	Many PFs prefer to get their own ATIS info. Read silently. Evaluate and discuss.	Obtains the ATIS information. - Read silently. Evaluate and discuss.

Notes and Justifications:
1.) D-ATIS provides the current weather, instrument approach procedures in use, and active runways, as well as details concerning runway and taxiway closures, wind shear reports, precise visibility values for individual runways, braking capability, bird activity, temporary obstructions (e.g. construction), land and hold short operations (LAHSO) 30 utilization, and any other relevant safety-related information. [39]
2.) The ATIS is a recorded message obtained by the crew using VHF radio or ACARS data link. [39]

D.13. CRUISE	Setup FMS for Descent and Approach	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Cruise flight prior to TOD	Setup FMS: Before TOD, modify active route for arrival and approach. May have the PM take over PF duties while setting up the FMS for approach.	Crosscheck automation setup.
Crew receives: **Any UM**	PF can choose to delay answering or sending STANDBY to finish the FMS setup.	If the workload is light, the PM can answer the UM.

Notes and Justifications:
1.) Ideally, an END OF DESCENT POINT within the terminal area of the destination airport, including speed and altitude, should be inserted while at cruise. All expected descent profile information should be programmed at cruise altitude to minimize low altitude programming. [19]
2.) The Boeing 777 FCOM has the PM set up the FMS for the approach and arrival [8], but many airlines have the PF set up the FMS while the PM performs the duties of the PF. [8]
3.) Set cockpit for approach: [19]

- Set up FMS active route based on arrival and approach.
- Enter/verify Vref on FMS APPROACH REF page.
- Set Vref airspeed bugs.
- Set baro altimeter and radio altimeter minimum bugs.
- Set autobrake.
- Set approach frequencies and course.

4.) FMS is setup from D-ATIS information, current clearance for STAR, expected runway, etc.

D.14. CRUISE	Approach Briefing	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Cruise flight prior to TOD	Performs briefing. Use the STAR and Approach charts to compare with FMS routing and constraints.	Becomes the PF. Follows the briefing.

D.14. CRUISE	Approach Briefing	
Crew receives: **Any UM**	PF can choose to delay answering or sending STANDBY to finish the briefing.	If the UM is answered, the PM resumes the briefing from the beginning.

Notes and Justifications:
1.) Normally, the approach briefing should be accomplished at cruise altitude when the destination ATIS information becomes available. This is supported by data from line operations safety audits (LOSA), which indicate that crews who conducted the arrival briefing after beginning descent committed 1.6 times more errors during descent/approach and landing, compared to those crews who briefed prior to top of descent**. [33, Appendix 5]** However, if this timing is impractical, the crew brief will be accomplished as soon as approach information is available. The pilot who will fly the approach briefs the approach. For monitored approaches the Captain will brief the required callouts and duties associated with the specific monitored approach. [19]
2.) Approach briefings contain items specific to the aircraft and the aircraft's avionics, but most of the briefing consists of reviewing the approach and landing IAP, weather and runway conditions, terrain considerations, and non-normal considerations. Additionally, the brief should include a review of the taxi operations and possible taxi route from the expected RW turn-off to the gate or parking area. [33, Appendix 5]
3.) Unless there is explicit discussion between the pilots during input of navigation settings in the FMS, there are not observable indications that modifications have been made by the pilot who did not implement the changes. [78]
4.) FSF study [5] shows a direct correlation between documented operational guidance (SOPs) together with training syllabi, evaluations and line checks that emphatically required pilots to compare their clearance with the FMS routing to the actual practice of pilots when flying the line. [5]

D.15. CRUISE	Top of Descent	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C is approaching TOD point computed by the FMS. (typically 40 minutes from landing.)	Enter cleared-to altitude in MCP ALT window. Check automation in correct profile mode.	Monitors TOD point.

Notes and Justifications:
1.) The ECON PATH descent with VNAV engaged should be used whenever possible. The ECON PATH descent is a function of the cost index. [19]
2.) One study shows that pilots fail to ensure the aircraft automation is performing as expected by failing to notice the aircraft has **NOT** acquired the top of descent point. [5]
3.) Distractions must be minimized, administrative and nonessential duties completed before descent or postponed until after landing. The earlier that essential duties can be performed, the more time will be available for the more critical approach and landing phases. [19]

4.2.5.5. Descent

E.1. DESCENT	AOC In-Range Call	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Crew must send arrival message to company via ARINC or voice. Crew workload is low. **Note 1**	Acknowledges to monitor ATC comms. Switch from LEGS page to CPDLC Comm page.	The duty to monitor ATC comms is passed to the PF. The PM states "*you have ATC comms, I'm talking to company*" After comms with AOC, the PM states that he has ATC comms.
Crew receives: **Any UM**	If a CPDLC UM is received while the PM's attention is directed to communicating with company, the PF may wait until the PM is done, or	N/A

E.1. DESCENT	AOC In-Range Call	
	may reply to ATC. This decision should be the judgment of the PF.	

Notes and Justifications:
1.) When communicating with company via voice or ACARS the pilot (PF or PM) is essentially "out of the loop" with the other crewmember and ATC. The prescribed handoff between the pilots states that when one is "off line" talking to company, the other has the ATC comms.

E.2. DESCENT	Transition Level	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
A/C climbs through transition altitude	Set and crosscheck the altimeters to local setting [19, 39]	Call out: "____FEET ____SET" [19] Set and crosscheck the altimeters to local setting. [39, 19]

Notes and Justifications:
1.) Domestic US: Transition Level = FL180 [39]

E.3. DESCENT	In-Range Checklist	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Also called Descent Checklist. [9]	Calls for In-range checklist at approx. 18,000 ft [19]	Performs checklist - PM performs the challenge and response.
Crew receives: **Any UM**	PF can choose to delay answering or sending STANDBY to finish the checklist.	If the UM is answered, the PM resumes the checklist from the beginning.

Notes and Justifications:
1.) The crew will want to complete the In-Range checklist prior to descending through 10,000 ft. [19]

E.4. DESCENT	Intermediate Level-Off Altitude	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Sets level-off altitude in MCP. Check automation mode. Monitor the automation has captured the level-off altitude.	Monitors last 1000 ft of level-off	
ATC instructs crew to descend: **UM23:** DESCEND TO [*level*] or ATC instructs crew to stop the descent above the previously assigned level. **UM220:** STOP DESCENT AT [*level*]	Read UM silently. Evaluate and discuss. Set altitude in the MCP alt window. Crosscheck. Tell PM to **ACCEPT** the clearance. Monitors last 1000'	Read UM silently. Evaluate and discuss. - Crosscheck. Send: **DM0:** WILCO. Monitor last 1000'. Make 1000' altitude call out.

Notes and Justifications:
1.) Automation mode awareness has proven to be a cockpit discipline and CRM problem. Pilots reprogram the FMS/MCP with new information during a mode change such as an intermediate level-off and are not aware of the automation mode change. [5]
2.) The altitude alerting system shall be used during all phases of flight to assist the flight crew in altitude awareness and to prevent deviation from assigned clearances. During descent, the flight crew shall set the next clearance altitude in the altitude selector window.

- With the autopilot ON, the PF will set the new clearance altitude in the altitude selector window.
- With the autopilot OFF, the PM will set the new clearance altitudes in the altitude selector window.
- Both pilots will verbally and visually acknowledge the cleared altitude set in the altitude selector window. [55]

3.) The purpose of reporting intermediate levels should be served by ADS-C. [55]

E.4. DESCENT	Intermediate Level-Off Altitude	
4.) On FMS arrivals or published arrivals (STARS) stored in the navigation data base, the clearance limit on the arrival (the lowest altitude) may be set in the MCP altitude window, provided VNAV is engaged to assure compliance on the arrival. [19]		

E.5. DESCENT	Approach Change	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
On Arrival		
Crew receives: **UM074:** PROCEED DIRECT TO [*position*] + **UM290:** DESCEND VIA [*procedure name*]	Read UM silently. - Evaluate and discuss. Setup FMS/MCP Crosscheck. Tell PM to accept clearance.	Read UM silently. If loadable, then transfer to FMS. Evaluate and discuss. - Crosscheck. Send: **DM:0** WILCO.

Notes and Justifications:

1.) The crew has just gone from a low/medium workload to a high workload to "sort out" the new approach procedure.
2.) Instrument approach procedures (IAP) are required by FAR Part 91.175(a) and [39].
3.) Clearance to "descend via" authorizes pilots to: [39]

- Vertically and laterally navigate on a STAR/RNAV STAR/FMSP.
- When cleared to a waypoint depicted on a STAR/RNAV STAR/FMSP, to descend from a previously assigned altitude at pilot's discretion to the altitude depicted for that waypoint, and once established on the depicted arrival, to navigate laterally and vertically to meet all published restrictions.

4.) Air traffic is responsible for obstacle clearance when issuing a "descend via" instruction to the pilot. The descend via is used in conjunction with STARs/RNAV STARs/FMSPs to reduce phraseology by not requiring the controller to restate the altitude at the next waypoint/fix to which the pilot has been cleared. [39]
5.) Maintaining the desired descent profile and utilizing the MAP mode (if available) to maintain awareness of position will ensure a more efficient operation. The crew should be aware of the destination weather and traffic situation and consider the requirements of a potential diversion. A review of the airport approach charts and pages, and a briefing for the approach and landing will be conducted. Complete this approach briefing as soon as practical, preferably before arriving at top of descent so the crew may give full attention to aircraft control. [19]

E.6. DESCENT	APU Start	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
On Arrival prior to FAF	Calls for APU start	Starts APU
Crew receives: **Any UM**	PF can choose to delay answering or send STANDBY to allow the PM to finish the APU start.	N/A

Notes and Justifications:

1.) If started in flight, the APU should be stabilized and up to speed prior to reaching the final approach fix. [19]

E.7. DESCENT	Setup for Bleeds-off Approach	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
On arrival, prior to commencing the approach. [19]	Call for bleeds off	Set up for bleeds off landing
Crew receives: **Any UM**	PF can choose to delay answering or send STANDBY to finish the Bleeds Off procedure	N/A

Notes and Justifications:

1.) Prior to commencing the approach setup for a bleeds off landing to meet performance requirements. [19]
2.) APU is required to be running prior to turning off the engine bleeds. [19]

E.8. DESCENT	**Data Link Altitude**	
RECOMMENDATION:	**USE CPDLC**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Descending through a "Data Link Altitude"		
Crew receives: **UM120:** MONITOR [*unit name*] [*frequency*]	Read UM silently. Check Comm frequency. Tell PM to acknowledge the UM.	Read UM silently. Check Comm frequency. Send: **DM0:** WILCO

Notes and Justifications:
1.) Data Link Altitude should be identified in the STAR. **See C.2. DATA LINK ALTITUDE Supplementary Notes.**

Recommendations:
1.) A "Data Link Altitude" is a **RECOMMENDED** standardized altitude for which ATC will use CPDLC as the primary means of communication. Before Data Link Altitude, all communication is by CPDLC, after Data Link Altitude the primary communication is voice. (See DATA LINK ALTITUDE Supplementary Notes)
2.) It is RECOMMENDED that the Voice Altitude is an automatic altitude that the controller will issue clearances and the crew will make requests when an aircraft is below that altitude.

E.9. DESCENT	**10,000 feet Altitude Callout**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
Aircraft descends through 10,000 feet MSL.	Acknowledge "Out of 10" callout.	Call "Out of 10" Select landing lights on. [19]

Notes and Justifications:
1.) Below 10,000' sterile cockpit procedures in effect. [19]
2.) Below 10,000', due to the increased need to clear for visual traffic, it is highly desirable to use the mode control panel functions to limit heads-down time. Maximum emphasis should be placed on programming the FMC with all known departure and climb information while on the ground and all known descent and landing information prior to descending below 10,000 feet MSL. While one pilot programs, the other pilot assumes total responsibility for clearing whenever the aircraft is in motion. [19]

E.10. DESCENT	**Approach Checklist**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
On descent.	Call for the Approach checklist when in the approach environment and after descending through the transition level, but no later than intercept heading to the final.	Perform checklist

Notes and Justifications:
1.) Complete the approach procedure before:
- The IAF, or
- Start of radar vectors to final approach course, or
- Start of visual approach [9]

4.2.5.6. Landing

F.1. LANDING	**Final Approach**	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
On descent, prior to approach intercept heading.	Verify ILS tuned and identified. Verify LOC and G/S pointers are shown. Arm APP mode.	Verify ILS tuned and identified Verify LOC and G/S pointers are shown. Monitor the approach.

Notes and Justifications:
1.) When performing CAT II / IIIA ILS, flight crew should closely monitor autoflight systems and ILS raw data to ensure proper localizer tracking. [19, 39, 11]
2.) When performing an actual CAT II / IIIA ILS approach and landing, flight crews should closely monitor autoflight systems and ILS raw data during the approach to ensure proper localizer tracking. [21]

F.2. LANDING	**G/S and LOC Alive / Capture**	
On ILS approach intercept heading	Acknowledge Callouts	Call "localizer alive" Call "Glide slope alive'

F.3. LANDING	**Final Approach Fix**	
Established on instrument approach.	Monitoring FAF passage and altitude.	

F.4. LANDING	**Flap and Gear Schedule**	
Established on instrument approach.	Call for flaps and gear	Select flaps and gear down

F.5. LANDING	**Landing Checklist**	
Established on instrument approach.	Call for landing checklist	Perform landing checklist

F.6. LANDING	**Altitude Callouts**	
On stabilized approach.	Acknowledge callouts	Monitor baro and radar altitude. Perform callouts.

Notes and Justifications:
1.) The optimum stabilized approach is defined as a flight on the glide path (visual or electronic) at a steady rate of descent, on the "target" approach speed, in the landing configuration, in trim, and with the proper thrust setting. [19]
2.) Altitude callouts for non-precision and CAT I precision approaches will be made using the barometric (electric) altimeters by the PM. The callouts will be: [19]

- At 1000 feet above touchdown zone (TDZE), callout "1000."
- At 500 feet above TDZE and at each 100-foot increment thereafter.
- Call "APPROACHING MINIMUMS" approximately 100 feet prior to DH, DA or DDA.
- At DH, DA or DDA/MDA PM will call "MINIMUMS."
- "APPROACH LIGHTS IN SIGHT" and/or "RUNWAY IN SIGHT."
- "100, 50, 30, 20, 10" FROM THE RADIO ALTIMETER.

F. 7. LANDING	**Decision Altitude**	
At DH, DA or MDA	Callout intentions to land or go-around.	Call out "Minimums."

Notes and Justifications:
1.) The decision made when passing DH, DA, DDA, or MDA is not a commitment to land. It is only a decision to continue the approach. It is possible, after passing the applicable minimums, that visual references may deteriorate, or the aircraft may deviate from the desired flight path to a point where a safe landing may not be assured. [19]

F.8. LANDING	**Transition to Visual Cues**	
DH, DA or MDA to touch-down	Satisfied that the total pattern of visual cues is sufficient.	Assist PF by Radar Altitude callouts

Notes and Justifications:
1.) Use of the autopilot to the minimum authorized altitude is desired to prevent "duck under" and allow the maximum amount of time for acclimation to visual cues prior to Autopilot disconnect. [19]

F.9. LANDING	Landing	
Touch-down	Verify ground spoilers deployed.	Verify ground spoilers and reversers deployed.

4.2.5.7. Missed Approach

G.1. MISSED APPROACH	Go-Around	
Sequence of Events	**Pilot Flying Procedures**	**Pilot Monitoring Procedures**
At DH, DA or MDA	Select TOGA. Callout: "Going Around" Perform go-around profile.	On Command from PF: * Raise gear and flaps * Select roll and pitch F/D modes * Select A/P * Inform ATC on the go-around
Notes and Justifications: 1.) Approaches will be considered unstable, and result in a missed approach if: • The airspeed is greater than +15 kts. or less than –5 kts. from target speed, OR • Vertical speed is greater than 1500 ft/min., OR • Engines are less than minimum spooled (at least 40% N1).		
G.2. MISSED APPROACH	**Missed Approach Procedure**	
Missed approach profile	Follow published missed approach procedure or ATC instructions. Set up for holding.	Verify and monitor initial heading and altitude. Verify holding setup.
G.3. MISSED APPROACH	**Holding**	
Entering hold	Assess available resources. Obtain EFC time from ATC. Obtain information to make diversion decision.	Assist PF as required.
Notes and Justifications: 1.) Good CRM dictates the PIC delegate flying duties to the FO to reduce workload. 2.) Begin speed reduction within 3 minutes prior to estimated arrival at the fix so as to arrive at the holding fix at or below the maximum authorized holding speed for the altitude. [39] 3.) During selection of the holding pattern in the FMC, verify proper holding pattern direction and inbound course are entered. PM monitors raw data. [39] 4.) Advise ATC immediately if an increase in airspeed is necessary due to turbulence or if unable to accomplish any part of the holding procedures. [39]		
G.4. MISSED APPROACH	**Return for Landing or Diversion**	
Decision must be made based on conditions and resources to choose to wait, return to land, or divert.	The Captain must see that the crew is provided with clear direction and leadership.	
Notes and Justifications: 1.) The possibility of a diversion should have been covered in the Approach Briefing. [19] 2.) If diversion to an alternate airport is necessary, pilots are expected to notify ATC and request an amended clearance. [39]		

4.3. Training Recommendations

4.3.1. General

Because CPDLC overlaps two basic airmanship skills, communication and cockpit automation, CPDLC training should be an integral part of a skills-based training program. CPDLC acceptance and procedure compliance is another issue for the company's training department. To guard against procedural non-compliance, the crew must clearly understand the procedure design rational. If trainees are provided with the philosophy and policies of CPDLC, preconceived mindsets can be overcome and knowledge can be acquired faster.

4.3.2. Documentation

The aircraft FCOM should have CPDLC operating instructions (with expanded procedures) in the communications section, but because the flight deck automation is so integrated with CPDLC, it may be better to locate the operating instructions within the FMS section.

The uplink and downlink message set with meanings and use should be included in the operations manual or other documentation required for the pilot.

The *Quick Reference Handbook* (QRH) should provide "CREW ACTIONS" for CPDLC cautions and warnings.

CPDLC authorization in the airline's operation specifications and its requirements in the minimum equipment list (MEL) depend on the location and type of operations performed by the airline as well as other considerations by the POI and the Flight department. This is a topic for future research.

4.3.3. Ground School

All of the current training methods and aids used for flight deck automation instruction are necessary for CPDLC training. PC-based training aids have become a necessity for effectively learning flight deck automation. Use of an FMS/CPDLC software training application is highly recommended for ground school and home study prior to the trainee advancing to cockpit procedures training (CPT) and certainly simulator training. This process is analogous to the trainee learning required call-outs prior to simulator training.

A ground school curriculum should be designed to use an interactive CPDLC PC simulator with flight scenarios. A PC tool is needed to teach and reinforce the CPDLC system controls, menus, alerts and sending or receiving ATC messages. The PC tool should be customized to replicate the customer's aircraft flight deck CPDLC and Automation configuration. The PC tool should also be capable of generating all UMs and DMs that would be expected in the ATC environment that the airline is expected to operate in.

The ground school curriculum should include equipment operating topics such as:

- CPDLC philosophy, policies and procedures
- CPDLC documentation:
  - MEL
  - EICAS Messages
  - QRH handling of EICAS messages
  - Operational bulletins
- CPDLC system set-up
- CPDLC operations specific to flight deck configuration
- CPDLC alerting and crew action
- Nominal and off nominal scenario 'walkthroughs' using PC based training tools

Ground school should include a study of the SC-214 message set and its use. The training is necessary to avoid ambiguities in the UMs by instructing when and how UMs and DMs are used. Training on using the message set in the ATC environment should include:

- Using CPDLC for negotiation
- Using free text
- Receiving conditional clearances
- When to abandon the use of CPDLC and not become distracted by it
- CPDLC lessons learned

4.3.4. CPT and Simulator Training

A cockpit procedural training (CPT) is used to develop and reinforce crew procedures, cockpit flows, crew coordination, required call-outs and communication prior to advancing to simulator training.

CPDLC training should be integrated into initial, upgrade and new equipment simulator training, as well as during the LOFT training that normally occurs after the simulator check ride. Because communication is a vital part of airmanship and cockpit management, simulator training should be used to reinforce CPDLC procedures in the context of an airline's operations. It is true that most of the simulator training is abnormal and emergency training and CPDLC would not be part of that training. However, when and how to switch from CPDLC to voice should be taught and practiced during CPT and simulator training.

If a flight department operates within a TBO FIM-S environment with tailored arrivals, the appropriate equipment, procedures, and scenarios should be designed to create realistic line operations. NextGen-type operations lend themselves very well to LOFT scenarios, but also should be integrated into basic simulator training.

CPDLC training should not be included in the "after the check-ride extra simulator period" for topics such as GPWS, TCAS, wind shear, because communication using CPDLC is too fundamental for effective cockpit discipline.

4.3.5. "Digital Hearback" Problem

CPDLC is a new way of communicating and different from commonly-heard ATC phraseology and aviation jargon. Previously learned communication habits may negatively bias a crew's compliance with CPDLC procedures. ATC phraseology (ATC Handbook 7110.65) has evolved over many decades and pilots have very strong associations and expectations with current ATC voice communications. Thus, very strong habit patterns have been built up that may be very resistant to change and may cause confusion with an ATC UM that does not phrase the clearance in exactly the same way. Perhaps this is a new digital version of the 'HEARBACK' problem [89].

Previously learned communication habits (both comprehension and response) may negatively bias new CPDLC training. Because communication is fundamental for all flight operations it is recommended that CPDLC training be integrated from ground school through line checks. This is an important consideration when updating the training sections of the FAA POI Handbook (8400.10) and company's Flight Operations Training Manual.

4.4. System Design Recommendations

The following system design recommendations are based on the outcome of the full flight task analysis of the selected message set (detailed results in Table 3-8). The recommendations address sub-topics of common issues identified.

4.4.1. Compliance with Clearances

- Many conditional clearances cannot be programmed directly into the FMS such as "AT [time] or [level] PROCEDE DIRECT TO [position]". The newest generation FMS on the 777 and 787 will alert the crew of the condition (time or level). It is recommended that future FMS designs be able to process conditional clearances with clear anticipatory advisory alerting to the pilot prior to the clearance becoming active (pilot should retain PIC role with having to manually execute the clearance).
- All FMS speed constraints are programmed in VNAV mode to act differently in climb and descent. The intent of the controller and the issued clearance UM must be able to be programmed into the FMS. UM intent and FMS capability must match.
- Limit use of free text—it is too easy to get distracted with writing an "email" to the controller.

4.4.2. Response Delay

- To reduce response delay, pilot decision aiding tools should be built into the FMS and displays. Clearances that require an evaluation of aircraft performance to meet an ATC clearance (e.g. RTA, climb or descent restriction) can delay a response to ATC. Decision aiding tools to evaluate the ability of the aircraft to meet constraints, especially under time pressure, will improve overall system capacity goals. A current example of this is the B-787's handling of conditional clearances. Prompts near the conditional fix are displayed as well as an ATC circle on the ND display showing the conditional fix location on the moving map display.

4.4.3. Loadable UMs

- To the extent possible, all UMs should be loadable.

4.4.4. Altitude Clearance

- The FMS adjusts speed only to meet the RTA time restriction during cruise, not during climb or descent. It is recommended that system design changes be made to allow RTA in descents and climbs. In cases where controlling to path, drag or thrust limitations prevent or exceed RTA parameters, then options should be presented to the crew so that ATC can be informed.

4.4.5. FMS Characteristics

- The controller must have a software application tool to quickly and easily assign along-track waypoints, and the FMS software must recognize the along-track waypoint. Adding or moving a waypoint in the crew's active flight plan must be simple for the controller and easy for the crew to examine and verify.
- The FMS must know that the waypoint is added or moved and logically sequenced in the LEGS page.
- The CPDLC/FMS should understand and then convert the sequence of UMs into a conditional clearance, then fly the FMS to comply with the clearance.
- For UM84: "AT [position] CLEARED [procedurename]" to be a loadable clearance ATC MUST give both a runway and an arrival that are compatible. If they are not compatible, the FM will detect this and not put up the load prompt. It is recommend that STARS or DP procedures that require explicit runways be notated in a salient way (for ATC and aircrews) and that FMS Nav Databases be coded to align with the charted procedures.
- Software logic should be designed to accept sequential clearance by converting it to a conditional clearance.
- FMS software should provide quick and easy pilot feedback for clearance decisions.

4.4.6. Display

- The NAV display should show the beginning and end of the offset track. The display should clearly show where the offset starts and ends.
- It will be important to incorporate— in both the ATC ground software and the FMS design—the capability for the controller to quickly and easily re-route aircraft using point and click technology.
- Quick-look decision aiding is desirable (map symbology rather than text fields in FMS) with an RTA clearance. First, to establish whether current aircraft performance can meet the RTA, then once navigating to a RTA waypoint, to provide system feedback to advise crew on progress on meeting RTA (ahead or behind).

- Selecting the clearance altitude contained in the UM display with the MCP Altitude knob will change the altitude color in the displayed UM. This is an efficient and easy feedback for the pilot to confirm that the dialed altitude matches the UM clearance altitude.

4.4.7. Alerting

Phase of flight inhibits should be considered for CPDLC alerting and display. For instance, during takeoff roll and through initial climb, the crew should not be distracted by flight deck effects that have no bearing on safety. This is common design practice with the current Master Caution and CAS systems.

4.5. CPDLC Procedure compliance

This section covers general compliance factors or areas of emphasis for general ATC clearance categories such as concatenated and conditional messages, as well as specific suggestions for clearances that are LOADABLE (can be directly loaded into the FMS), and crew procedures for CPDLC screen set-up. Additional compliance issues were explored for ATC Uplink ALTITUDE, SPEED, and ROUTE clearances. This section captures unique features of specific UMs that should be watched or regarded when evaluating compliance.

A more fine-grained analysis was done in the PROCEDURES RECOMMENDATIONS section that uses a phase of flight analysis. A phase of flight analysis approach was helpful in developing compliance attributes. This method of embedding CPDLC procedures into the overall context of a 'typical' flight allowed a fuller understanding of crew tasks and responsibilities that may be concurrent or subsequent to CPDLC communications. Consideration should be given to tasks that make up the normal workload of flight crews, such as accomplishing checklists, configuring the aircraft for takeoff and landing, programming flight management systems (FMS), and managing auto-flight modes.

The first subsections address overall crew performance as it relates to safety of operations. These areas require special emphasis when evaluating crew compliance with CPDLC. CPDLC, if imported to the terminal or surface operation phases will require increased vigilance so that other safety margins are not sacrificed.

4.5.1. Special Emphasis Areas

The use of CPDLC will put additional demands on the crew's visual monitoring workload. Special Emphasis Areas, as adopted from the ATP Practical Test Standards [44], are included to ensure that safety-critical tasks are not undermined by the crew's use of CPDLC. Special emphasis must be placed on areas of aircraft operations considered critical to flight safety. Among these are:

1. Positive aircraft control (designated PIC, PM, or PF must be watching the aircraft regardless of communication responsibilities)
2. Procedures for positive exchange of flight controls (should it be necessary to initiate #1 above)
3. Special use airspace and other airspace areas (awareness of terminal area and low altitude airspace while engaged with CPDLC)
4. Collision avoidance procedures (same. Terminal area 'SEE and AVOID' is a primary responsibility in VMC conditions.)
5. Runway incursion avoidance and good cockpit discipline during taxi operations (CPDLC should not distract from this hazard.)
6. Controlled flight into terrain (CFIT); CPDLC should not distract the crew when operating in a terminal area with obstructions. Positive control of aircraft and situational awareness must be maintained. CPDLC will be heads down and cockpit discipline demands that one pilot is head up at all times.
7. Disciplined use of checklists

The tables below break CPDLC compliance factors into both general and specific UM categories. This scope of study was limited to the analysis of ATC clearance uplinks only. If a training issue was observed it will be noted within each category. The contents of the analysis are listed below:

General Criteria for CPDLC Compliance:

1. Pilot response to ATC Uplinks (Table 4-3)
2. CPDLC Display Clearing (Table 4-4)
3. Response Delays – General (Table 4-5)
4. FMS Operations – General (Table 4-6)
5. Altitude Clearances – General (Table 4-7)
6. Speed Clearances – General (Table 4-8)
7. OFFSET Clearances – General (Table 4-9)

Complex UMs – General (

8. Table 4-10)
9. UM Concatenation – General (Table 4-11)
10. Conditional Clearances – General (Table 4-12)
11. Loadable Clearances – General (Table 4-13)

Compliance Criteria for Specific Ums (Table 4-14)

1. Specific Altitude UMs
2. Specific Speed UMs
3. Specific Route Modification UMs

Table 4-3. Pilot Response to ATC Uplinks

Pilot Response to ATC Uplinks
Compliance Factors • When pilots accept or reject a clearance they should monitor that the prompt changes from ACCEPTING to ACCECPT. With a rejection it will change from 'REJECTING' to 'REJECT.' This is the crew's indication that the response has been validated and received by the ground controller.

Table 4-4. CPDLC Display Clearing and Set-Up

CPDLC Display Clearing and Set-Up
Compliance Factors • After the crew has responded to a UM (e.g., WILCO), the crew should clear the ATC message display window for the next incoming message. • ATC message window clearing is accomplished by pressing "CANCEL" button. • Pressing the CANCEL button 'tears down" the ATC message window and removes the •ATC MSG from the EICAS display (assuming no ATC messages in the ATC Message LOG that have not been responded to) • Clearing the ATC Message Screen will give the crew the full visual alerting of a new incoming message. The crew will hear the chime, the •ATC MSG will 'pop up' and the ATC Message Window on the EICAS (744, 737 NG, 777) or glass MCDU (787) will also pop up. • If the crew does not clear the screen for the next message, they will still hear the chime but not get the full visual alerting of the pop up ATC message window or the •ATC MSG. • In some instances ATC Messages are uplinked in quick succession and the crew will not be able to clear the screen. However, it is good CPDLC practice to clear the screen when able. • The crew should have a default (or standard) CPDLC set-up after each UM clearance has been responded to. In the case of the B-777, they should have the COMM Manager up full time so that the load prompt is clearly visible. Since CPDLC will become the primary means of communication, the crew should establish a default configuration for CPDLC screens. In the case of the B-777 and B787 it may mean always having the COMM

CPDLC Display Clearing and Set-Up
Manager screen available. If crew needs to view another screen or synoptic then they should return to the Message Manager when done. On the legacy airplanes with MCDUs the crew should return to the ATC Page when they are done with any other page they are using (LEGS, VNAV, PROG, etc.) • The crew uses a company standardized, or 'default' CPDLC display set-up. This is analogous to having ATC and company radios set to a standard COM 1 & COM 2 set-up. It ensures that CPDLC messages with LOAD prompts are always visible and salient (similar to hearing your call sign). For some model types (e.g. B748) this may mean having the ATC page on the on-side MCDU. Although this may seem unnecessary for some types (those with an EICAS display or glass CDU display of the ATC message), there is also potential for not seeing a LOAD prompt (e.g., on the B777 the LOAD prompt is only displayed on the COM Manager Window). If the LOAD prompt is missed, the crew may respond to the message with an ACCEPT before realizing there is a preview capability with the LOAD prompt. Loading the clearance allows the crew to visualize the provisional flight path and evaluate for weather, traffic, or operational suitability prior to committing with a WILCO. Cancelling the UM clears the screen after a response is made (e.g. WILCO), clears the ATC Message annunciation on the MFD, and creates a 'clean' screen for the next incoming message. • Crew may not wait for ACCEPTED to turn green before canceling; which is the crew's 'receipt' that ground has received your downlink response.

Table 4-5. Reducing Response Delays - General

Reducing Response Delays - General
Compliance Factors • Injecting a delay into any classical control system makes the system difficult to control. A time delay in input-output relationships is a common property of many technological processes containing complex and interrelated systems such as the NextGen air traffic control system. "Dead-time" affects both the performance and stability of the system. Response "dead-time" can cause a delay for the ATC controller that may affect responsiveness to tightly coupled, tight RNP separation issues. **Complex Clearances** There are no formal CPDLC definition of a Complex UM, but at least one property can make a UM difficult to comply with—the time the crew needs to analyze the performance of the aircraft against the constraints in the clearance. One example is UM49: "CROSS [*position*] AT AND MAINTAIN [*level*]" Other examples of complex UMs: • UM50: CROSS [*position*] BETWEEN [*level*] AND [*level*] • UM84: AT [*position*] CLEARED [*procedure name*] • The controller would rather the crew reject a crossing restriction clearance quickly [APPENDIX D – ZMA AND MIA TRACON Observation] if there is any question that the aircraft will make the crossing restriction, than delay an acceptance response. If the crew delays an acceptance response in a tightly-coupled environment it increases the probability that the controller may have to issue an altitude change or vector to the other conflicting aircraft. • UM50: CROSS [*position*] BETWEEN [*level*] AND [*level*] is a candidate UM that may lead to negotiations. This clearance in voice communications usually results in negotiations between the crew and the controller. If the crew feels that it might be "tight" making an altitude restriction, they will usually say so immediately. The controller has instant feedback that the crew may not be able to make the altitude restriction. The controller will usually tell the crew to do the best they can, or give then an altitude they can meet, and adjust the other aircraft for separation accordingly. • The lack of immediate feedback and the CPDLC system delay, plus the time spent to check aircraft

Reducing Response Delays - General
performance may not be workable for the controller. • Although sometimes formality during negotiations is lacking, the JO 7110.65 clearly states: "The phrase *'do the best you can'* or comparable phrases are not valid substitutes for an amended clearance with altitude or speed restrictions." [41], Para 4-2-5. Route or Altitude Amendments. • The FMS for B733 and 744 will display "UNABLE NEXT ALT" scratch pad message if it calculates that the crossing restriction cannot be made. This **only** occurs after selecting executing the modification (clicking EXEC key). • When a step-climb clearance is received, the crew should verify the altitude is within the aircraft performance capabilities before accepting the clearance. • When necessary to reject the clearance due to aircraft performance, it is recommended the crew include a reject reason with their clearance rejection DM. If a reason for not accepting the higher altitude is due to other than aircraft performance, then a free text description of the reason or a voice contact is recommended.

Table 4-6. FMS Operations - General

FMS Operations - General
Compliance Factors **Speed Control** • The crew should maintain ATC speed clearances, such as UM310: AT [*level*] MAINTAIN [*speed*] using the MCP panel, and use FMS speed restrictions from published departures and arrivals. • The "AT OR AFTER" crossing restriction is the easiest RTA restriction to meet because it only requires delay crossing a waypoint. Increasing speed to "make up time" is much more difficult. • The Honeywell FMS adjusts speed only to meet the RTA time restriction during cruise, not during climb or descent (although RTA in climb or descent is expected to be certified in 2014-15). • As with other route modifications, loadable or not, SOPs should require crews evaluate the modified route for discontinuities and other operational issues/constraints with flight plan. • For loadable UMs, it is necessary to perform a LEGS page verify and "clean up" after accepting the clearance. The crew must evaluate whether they are within RNP limits with a vertical or lateral route modification. • Meeting RTA requires accurate winds. System should allow constant wind updating to improve the accuracy of RTA predictions, or the crew should enter winds when auto-update is not available. • All airspeeds in the LEGS page are considered by FMS as AT OR BELOW constraints. [9] Therefore, as the FMS software is currently designed, the intent of UM108 cannot be loaded into the FMS. The lower end of the range could be loaded into the FMS, but the crew will typically want a faster speed. • It is typical for the crew to take extra time in responding to an RTA clearance due to the infrequent use of the clearance (0.066% of the clearances) and the crew unfamiliarity of the RTA feature. • If the modified flight plan includes the added waypoint and all subsequent waypoints to the destination, then the crew must examine and verify that this updated flight plan is the same as the current flight plan. If the full-route flight plan is long, the crew may not take the time to look at it closely and miss something, or the crew may take too long to study the new flight plan and the reply time expires. • Currently, the B777 and B787 avionics do not recognize UM290: DESCEND VIA [*procedure name*]. • The following concatenated message contains waypoint altitude constraints and logic for both the crew and the FMS to use and understand: MAINTAIN [level] + THEN + AT [position] CLIMB AND MAINTAIN [level] VIA [procedure name] • The arrival procedure (STAR) must be associated with a runway selected in the FMS. If the [*procedurename*] contained in UM84 is not associated with the runway selected in the FMS, then the CPDLC system will reject

FMS Operations - General
the UM. CPDLC will display: “UNABLE Clearance-Runway Arrival combination not compatible” **VNAV** • If the crew does not have VNAV mode engaged on the MCP, the FMS will still load the UM, but the guidance/autopilot will only fly what is selected on the MCP and not follow the navigation and constraints provided by the FMS to meet the altitude restriction. If the crew is flying a clearance with vertical restrictions or descents with vertical constraints, and chooses to do so with MCP vertical mode selections, then care must be taken to make sure the aircraft will meet the clearance. • A VNAV waypoint speed constraint is interpreted as a “cannot exceed” speed limit, which applies at the waypoint and all waypoints **preceding** the [*position*] waypoint if the waypoint is in the climb phase; or all waypoints **after** it if the [*position*] waypoint is in the descent phase [112].

Table 4-7. Altitude Clearances - General

Altitude Clearances - General
Compliance Factors **Intermediate Level Off** • When the crew initializes the FMS during preflight, the cruise altitude is entered in the CRZ ALT parameter on the CRZ page. Standard procedure for intermediate level off is to dial the cleared altitude in the MCP Altitude Window and **not** change the altitude value in the CLB or CRZ pages. The intermediate level-off procedure is currently taught by most airlines and flight academies, such as Pan Am Flight Academy in Miami, FL [66]. • The intermediate level-off procedure is used during descent. Aircraft performance is not an issue on descent, but lower altitude factors such as turbulence and excessive fuel burn are considered by the crew. **Climb and Descent** • When a step-climb clearance is received, the crew should verify the altitude is within the aircraft performance capabilities before accepting the clearance. • For UM27: CLIMB TO REACH [level] BY [position], the crew must monitor the climb to ensure A/C is level at [*level*] by [*position*] and cannot be loaded into the FMS. • UM50: CROSS [position] BETWEEN [level] AND [level], altitude restriction clearance is seldom used in flight-plan-based ATC operations because it requires the controller to manually "thread the needle" (aircraft) between two other aircraft, decreasing the margin of error and increasing the risk of conflict. It is safer and easier to vector an aircraft instead of stacking three aircraft on top of each other while climbing or descending. • When necessary to reject the clearance due to aircraft performance, it is recommended that the crew include a reject reason with their clearance rejection DM. If a reason for not accepting the higher altitude is due to other than aircraft performance, then a free text description of the reason or a voice contact is recommended.

Table 4-8. Speed Clearances

Speed Clearances
Compliance Factors • ATC will express all speed adjustments in terms of kts. based on indicated airspeed (IAS) in 10 knot increments except that at or above FL 240 speeds may be expressed in terms of Mach numbers in 0.01 increments. The use of Mach numbers is restricted to turbojet aircraft with Mach meters. [39] 4−4−12-b. Speed Adjustments

Speed Clearances
• Pilots complying with speed adjustments are expected to maintain a speed within plus or minus 10 kts. or 0.02 Mach number of the specified speed. [39] 4−4−12-c. Speed Adjustments • TBO may require more restrictive speed requirements, such as plus or minus 5 kt or 0.01 Mach • If the controller gives **UM56**: CROSS [*position*] AT OR LESS THAN [*speed*] as a clearance, then the crew may ask "Can we "keep the speed up" until just prior to crossing waypoint?" **Answer**: The fact that the controller gave the clearance to cross a waypoint at a given speed implies that the speed before the waypoint is at pilot's discretion. • **UM61**: CROSS [position] AT AND MAINTAIN [level] AT [speed] is not loadable, yet. This is the same issue as UM56. In a **climb**, the FMS will immediately slow. The FMS will not increase speed greater than the TGT SPD in the VNAV CLB page. • **UM108**: MAINTAIN [speed] OR GREATER is not an 'FMS friendly' uplink message. A speed constraint is interpreted as a "cannot exceed" speed limit. • A waypoint speed constraint is interpreted as a "cannot exceed" speed limit, which applies at the waypoint and all waypoints preceding the waypoint if the waypoint is in the climb phase— or all waypoints after it, if the waypoint is in the descent phase [112]. • Entering a speed/altitude pair on a cruise waypoint will turn the waypoint into a climb or descent waypoint. Entering a speed-only value (Mach-only, CAS is not supported), then that will be a new cruise speed target applied **after** that waypoint (this feature is called **Cruise Speed Segments** and may not be available on all FMS).

Table 4-9. OFFSET Clearances - General

OFFSET Clearances - General
Compliance Factors • Offset is not only used for side-stepping weather, it is also used by ATC for RNAV routes as described in the *Aeronautical Information Manual*. Unpublished RNAV routes are direct routes, based on area navigation capability, between waypoints defined in terms of latitude/longitude coordinates, degree−distance fixes, or offsets from established routes/airways at a specified distance and direction. [AIM 5-3-4-3(c)] • If this UM is to be used to define an RNAV route based on an offset from an established route/airway, then the [route] will need to be defined in this UM. [7110.65, 4-4-i-4] • When clear of weather, the crew requests and ATC clears direct to next waypoint. The crew does not want to turn to get back on the original track [66]. • **UM64**: OFFSET [*specified distance*] [*direction*] OF ROUTE should be used only for weather deviation or strategic separation. If the crew requests the offset for weather deviation, ATC should clear the crew direct to next waypoint after deviating. This reduces the amount of deviation required and easier for the crew to select when they can fly direct to the next waypoint. • ATC should advise the crew when or where the offset will terminate.

Table 4-10. Complex UMs - General

Complex UMs - General
Compliance Factors Complex UMs • For UM255: CROSS [*position*] BETWEEN [*RTAtimesec*] AND [*RTAtimesec*] no current FMS will accept user input to cross a waypoint between two times (i.e. time window). It is not likely that FMS OEMs are considering including this feature in an FMS. Use of this type of clearance is very rare. The Pacific Oceanic ATC documented use of this UM only 2 out of 2.3 million times over a ten year period. [ATC CPDLC website] • UM258: CROSS [*position*] AT OR AFTER [*RTAtimsec*] AT [*level*]. FMS does not calculate RTA speed during a climb.

Table 4-11. UM Concatenation - General

UM Concatenation - General
Compliance Factors • If a concatenated clearance is received, the crew must ACCEPT or REJECT the clearance in its entirety. In CPDLC systems that can autoload clearances directly into the FMS (B787, B777, MK 2 on legacy) the FMS system will only accept the part of a concatenated message that passes the FMS pre-load checks. If the crew ACCEPTS the concatenated message and if the total message or part of the message is LOADABLE and if the LOADABLE message passes the FMS pre-load checks, THEN a LOAD prompt will be displayed. The crew must have training to recognize that some parts of the concatenated message may not be loadable and must manually load if necessary. (Some non-loadable elements may not be modifications that need to be inserted into the FMS.) • SPR-H, Sect. 5.3 Safety and Performance Requirements states "The flight crew shall execute clearances, received in a concatenated message, in the same order as displayed to the flight crew." • The concatenation of two or more UMs can be interpreted to be performed sequentially or in parallel. • In the concatenated UM example: UM20: CLIMB TO [*level*] + UM116: RESUME NORMAL SPEED The crew is to interpret the clearance as two separate clearances performed at the same time. Therefore, the crew will begin their climb and return to their normal climb speed at the same time.

Table 4-12. Conditional Clearances - General

Conditional Clearances - General
Compliance Factors Many conditional clearances cannot be programmed directly into the FMS prior to meeting the position or condition of the conditional clearance (such as AT [time] or [level] PROCEED DIRECT TO [position]). The obvious risk is that the crew may become distracted and forget or delay the input of the clearance. However, the newer generation FMSes on the 777 and 787 will alert the crew of the condition (time or level) as the aircraft approaches the conditional clearance condition or position. • The Boeing 787 provides a sidelink to 'pop up' a visual crew reminder for conditional clearances. As the aircraft approaches the point where the clearance becomes effective, the visual reminder to execute the

Conditional Clearances - General
clearance 'pops up' in the center MFD CDU. The Boeing 777 is expected to also have this capability.

Table 4-13. Loadable Clearances - General

Loadable Clearances - General
Compliance Factors • The B777, B787, and Mark 2 CMU can directly load clearances into the FMS. If the ATC clearance passes the pre-load checks, a LOAD prompt appears. On the B787, the LOAD and CANCEL buttons appear adjacent to each other. Care must be taken to select the proper button. • If a concatenated message is sent to the aircraft and it contains both loadable and non-loadable elements, only the loadable elements can be loaded into the FMS. Crews need training on this issue so that the non-loadable message elements are properly executed. • When the load button is pressed, a provisional flight plan is created and displayed on both the FMS page (e.g., LEGS Page) and the ND. The EXEC light turns ON. Crew needs to review the modification prior to EXECUTING and responding to ATC (WILCO or REJECT).

Table 4-14. Compliance Factors for Specific Altitude, Speed and Route UMs

UM	Compliance Factors
UM 20: ALTITUDE CLEARANCE CLIMB TO [level]	• When the crew initializes the FMS during preflight, the cruise altitude is entered in the CRZ ALT parameter in the CRZ page. Standard procedure for intermediate level off is to dial the cleared altitude in the MCP Altitude Window and not change the altitude value in the CLB or CRZ pages. This procedure is currently taught by most [66] • The same procedure is used for intermediate level off during descent. Aircraft performance is not an issue on descent, but lower altitude factors such as turbulence and excessive fuel burn are considered by the crew. • FMS "UNABLE CRZ ALT" will annunciate if the aircraft cannot meet the altitude. However, there is some delay in triggering this message (can be 10-15 seconds). Care should be taken to verify aircraft performance for the higher altitude before accepting the altitude clearance. Use of STANDBY may be appropriate. • The crew should be aware of the misleading indication of the ND green arc. • The green arc provides an instantaneous prediction of where along the track the aircraft will reach the altitude dialed in the MCP ALT window. As the aircraft rate of climb decreases at higher flight levels, the green arc will move down the track. Therefore, the green arc can mislead the crew, especially early in the climb, to where the aircraft will reach TOC. • Crew should use the performance information contained in the FMS LEGS page and should update the wind information in the LEGS page. **Climb and Descent** When necessary to reject the clearance due to aircraft performance, it is recommended the crew to include a reject reason with their clearance rejection DM. If a reason for not accepting the higher altitude is due to other than aircraft performance, then a free-text description of the reason or a voice contact is recommended. Reduce the complexity of the UMs.

UM	Compliance Factors
	Dialable Uplinks (Boeing 787) • When the CPDLC avionics communication management function (CMF) receives "UM20: CLIMB TO [FL350]," the 35000 altitude value is displayed in the lower half of the MCP ALT window after the uplink has been ACCEPT'ed. The displayed altitude value is a visual aid to help the pilot dial the correct altitude in the MPC ATL window. See Figure 3-1for a graphical representation. • The CMF also uses the altitude value to provide another pilot visual aid when using dial feedback. When the pilot dials the altitude in the MPC ALT window to match the uplinked altitude value, the alphanumeric altitude value contained in the UM displayed in the AUX panel and the on the MFD if the UM is displayed from the ATC page, the text turns from white to green. This feature is called "dialable" and the UM is a "dialable" UM.
UM027: CLIMB TO REACH [*level*] BY [*position*]	• UM27 is not loadable. • UM27 is dialable for B777 and B787 (altitude is displayed in the MCP altitude window as a prompt only). • The FMS calculates whether the aircraft can meet the altitude crossing restriction only after it the pilot executes the modified flight plan. If the crossing restriction is "tight," then the crew could use the FMS to calculate the aircraft climb performance. The crew could change the vertical navigation mode to ALT HOLD to allow the FMS to calculate the aircraft performance. If the aircraft can make the crossing restriction the crew can return to VNAV and ACCEPT the clearance. If not, reject the clearance and maintain present altitude. This may be a technique to the procedural step of verifying compliance with the ATC clearance. The crew is responsible for ensuring clearance compliance. • If there is any question of meeting the climb restriction, the crew will usually enter the waypoint in the FMS to check whether the aircraft can make the climb restriction. • It is important for the crew to verify that the aircraft can meet the climb (or descent) restriction prior to accepting the clearance because of the inherent delay of CPDLC. • The controller does not have a UM that gives an along –track altitude restriction such as [position] = [10 NM WEST OF ENL]. Therefore, the controller must create a Latitude/Longitude or Place, Bearing, Distance (PBD) waypoint and will most likely not be exactly on the track. The controller must then clear the crew direct to the waypoint or insert the waypoint into their flight plan (UM83), then clear them "REST OF ROUTE UNCHANGED." This creates a route discontinuity and an assumption that the crew can remove the discontinuity, so for the controller to give a waypoint restriction where there is NO waypoint, the controller must define a waypoint, clear the aircraft to that waypoint, then give the climb/descent restriction at that waypoint.
UM047: CROSS [*position*] AT OR ABOVE [*level*] (climb)	This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message, the crew must access the ATC LOG. Before accepting UM47, the crew should be satisfied that the aircraft can make the climb restriction. • If the FMC predicts the airplane will not reach an altitude constraint, the FMS-CDU message: **UNABLE NEXT ALTITUDE** displays. Speed intervention can be used by

UM	Compliance Factors
	pushing the IAS/MACH selector and manually setting a lower airspeed to provide a steeper climb. • The same thing is done using VNAV CLB page by selecting a slower climb speed or the MAX RATE or MAX ANGLE speed. • If "A" is omitted, the A/C will most likely level off at FL270 prior to FRANC and then continue to climb after passing. • If 27000 is set in the MCP, the A/C will level off at FL270. It is recommended that the crew always enter the crossing restriction in the LEGS page. Crew will verify that the A/C can meet the crossing restriction. The FMS will annunciate if the A/C cannot meet the crossing restriction by annunciating "UNABLE NEXT ALTITUDE" in the FMS scratchpad.
UM049: CROSS [*POSITION*] AT AND MAINTAIN [*LEVEL*]	This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message the crew must access the ATC LOG. Before accepting UM49, the crew should be satisfied that the aircraft can make the climb restriction. It is recommended that the crew always enter the crossing restriction in the LEGS page. Crew will verify that the A/C can meet the crossing restriction. The FMS will annunciate if the A/C cannot meet the crossing restriction by annunciating "UNABLE NEXT ALTITUDE" in the FMS scratchpad. The FMS will climb the A/C as soon as the new clearance altitude is entered in VNAV page and the MCP ALT window is set. If the crew wants to delay the climb, it is recommended that the MCP ALT window be used to initiate the climb. A crew error could start the climb earlier than the crew wants, because setting the cleared altitude (e.g. FL350) in the MCP ALT window and setting 350 in the VNAV CRZ page and clicking EXEC will start the A/C climb to 350.
UM050: CROSS [*POSITION*] BETWEEN [*LEVEL*] AND [*LEVEL*]	UM50 is loadable on the B787 and B777. UM20: CLIMB TO [level] is NOT loadable, but is dialable. When the crew received UM20 concatenated with UM50 they will dial in the cleared altitude from UM20 and load the altitude restriction contained in UM50. This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message, the crew must access the ATC LOG. The FMS will display "UNABLE NEXT ALT" scratch pad message if it calculates that the crossing restriction cannot be made. This situation occurs only after executing the modification (clicking EXEC key). This type of clearance in voice communications usually results in negotiations between the crew and the controller. If the crew feels that it might be "tight" making an altitude restriction, they will usually say so immediately. The controller has instant feedback from the crew that they may not be able to make the altitude restriction. The controller will

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td></td><td>usually tell the crew to do the best they can or give then an altitude they can meet and adjust the other aircraft for separation accordingly.

This type of feedback is necessary for manual separation. The lack of immediate feedback and the CPDLC system delay plus the time spend to check aircraft performance may not be workable for the controller.

NOTE: Although there is sometimes lack of formality during negotiations, the JO 7110.65 [41] clearly states: “The phrase “do the best you can” or comparable phrases are not valid substitutes for an amended clearance with altitude or speed restrictions.”</td></tr>
<tr><td>UM056: CROSS [POSITION] AT OR LESS THAN [SPEED]</td><td>This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message, the crew must access the ATC LOG.

FMSes are designed to handle waypoint speed crossing restrictions differently for climb and descent. In climb the speed restriction is handled before the waypoint, and in the descent the speed restriction is handled after the waypoint. The FMS considers all speed constraints as “at or below” the speed.

Climb:
• FMS Speed Control prior to Waypoint:
Assigning an airspeed restriction less than the VNAV CLB airspeed/Mach to a waypoint in the LEGS page will cause the FMS to immediately slow to the crossing airspeed, and maintain that airspeed until it passes the waypoint.
Note that the FMS can NOT cross a fix at airspeed greater than the airspeed/Mach displayed in the CLB page LSK L2 position (ECON SPD, TGT SPD, etc.).
• FMS Speed Control after Waypoint:
After the waypoint, the FMS increases speed back to the VNAV CLB airspeed/Mach.

Descent:
• FMS Speed Control prior to Waypoint:
During descent, the FMS maintains the descent airspeed until just prior crossing the waypoint. The FMS begins slowing the aircraft to the crossing airspeed sufficient distance from the waypoint for the aircraft to cross the waypoint at the crossing airspeed. The FMS maintains the airspeed until the next airspeed restriction (e.g., 250kts/10,000 ft.). In the example of CROSS [CHERI] AT OR LESS THAN [310], the FMS began slowing the aircraft from 335kts to 310kts 7nm from CHERI.
• FMS Speed Control after Waypoint:
The FMS maintains the airspeed restriction until it encounters another speed restriction. For example, the FMS begins slowing to 250kts for the 10,000 ft altitude restriction.

Cruise:
If a speed/altitude pair is entered on a cruise waypoint, the waypoint will become a climb or descent waypoint. A speed-only value (Mach-only, CAS is not supported) becomes a</td></tr>
</table>

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td></td><td>new cruise speed target that will apply after that waypoint (this feature is called Cruise Speed Segments and may not be available on the older 747 FMS).

In domestic ATC flight plan-based trajectory voice operations, it is extremely rare that a controller will issue this clearance in cruise flight. From the “ATC Data Link” website, it is documented that UM56 was used 3 out of 2,267,258 times over a ten year period in the South Pacific oceanic routes. It does not indicate if the three uses were in climb, descent, or cruise.

Because UM56 is loadable, it is recommended that the crew not load UM56 into the FMS for a speed restriction during climb and that they navigate using the MCP to meet the intent of the clearance. Loading and navigating UM56 during descent is recommended.

Target airspeeds are changed by entries in the DESCENT page. Entries made on the LEGS page are “at or below” and may limit the target speed.

(Boeing FCOM: 11.31.20)

Crew may get clearance too soon and may not want to execute on the clearance. They may want to wait, but will have to remember. In other words, there is a CROSSING restriction for a waypoint of a slower speed, but if the waypoint is 100 miles ahead, crew may want to wait to get closer to the waypoint before slowing to the waypoint speed constraint.</td></tr>
<tr><td>UM061: CROSS [POSITION] AT AND MAINTAIN [LEVEL] AT [SPEED]</td><td>This is the same issue as UM56. In a climb, the FMS will immediately slow. The FMS will not increase speed to greater than the TGT SPD in the VNAV CLB page.

UM61 requires the crew to maintain an altitude, which is done using the “intermediate level-off method” by setting 15000 in the MPC ALT window.

A waypoint speed constraint is interpreted as a “cannot exceed” speed limit, which applies at the waypoint and all waypoints preceding the waypoint if the waypoint is in the climb phase, or all waypoints after it if the waypoint is in the descent phase [112].

Climb:
• FMS Speed Control prior to Waypoint:
Assigning an airspeed restriction less than the VNAV CLB airspeed/Mach to a waypoint in the LEGS page will cause the FMS to immediately slow to the crossing airspeed, and maintain that airspeed until it passes the waypoint.
• FMS Speed Control after Waypoint:
After the waypoint the FMS increases speed back to the VNAV CLB airspeed/Mach.
Descent:
• FMS Speed Control prior to Waypoint:
During descent, the FMS maintains the descent airspeed until just prior crossing the waypoint. The FMS begins slowing the aircraft to the crossing airspeed sufficient distance from the waypoint so the aircraft crosses the waypoint at the crossing airspeed. The FMS maintains the airspeed until the next airspeed restriction (e.g., 250kts/10,000 ft.). In the example of CROSS [CHERI] AT OR LESS THAN [310], the FMS began slowing the aircraft from 335kts to 310kts 7nm from CHERI.</td></tr>
</table>

UM	Compliance Factors
	• FMS Speed Control after Waypoint: Airspeed is maintained after the waypoint. UM61 is clear that the controller wants the crew to cross ANX at and maintain 15,000 ft., but the crew may understand that the speed until ANX is at pilot's discretion and after ANX the crew is to **maintain** 280 kts. A crew may associate "MAINTAIN" with only the altitude and not the speed, fly at 280 kts to ANX, and then speed back up after ANX. This process is exactly what the FMS does in the climb with this climb restriction. Crew must remember to follow this procedure when approaching the waypoint. Because they cannot tie altitude with MACH, they have to just put MACH in the LEGS page and use MCP only for altitude.
CONCATENATED CLEARANCE: UM20: CLIMB TO [*LEVEL*] + UM116: RESUME NORMAL SPEED	Not loadable. The concatenation of two or more UMs can be interpreted to be performed sequentially or in parallel. This message will include a modifier (UM165: THEN) between UMs to signify the UMs are to be performed in order and sequentially. In this example, the crew is to interpret the clearance as two separate clearances performed at the same time. Therefore, the crew will begin their climb and return to their normal climb speed.
UM106: MAINTAIN [*SPEED*]	**Cruise:** • Entering a speed/altitude pair on a cruise waypoint will turn that waypoint into a climb or descent waypoint. A speed-only value (Mach-only, CAS is not supported) will be a new cruise speed target that will apply **after** that waypoint (this feature is called **Cruise Speed Segments** and may not be available on the 747-400 FMS). • ATC will express all speed adjustments in terms of kts. based on indicated airspeed (IAS) in 10 knot increments, except that, at or above FL 240 speeds may be expressed in terms of Mach numbers in 0.01 increments. The use of Mach numbers is restricted to turbojet aircraft with Mach meters.[43] • Pilots complying with speed adjustments are expected to maintain a speed within **plus or minus 10 kts.** or **0.02 Mach** number of the specified speed. [39] 4−4−12-c. Speed Adjustments] • FMS does have a way to enter an FMS command to maintain an A/S or **greater**. • All airspeeds are considered by FMS as AT OR BELOW constraints. [21: ***Ch 11, Sect. 31***]
UM188: AFTER PASSING [*POSITION*] MAINTAIN [*SPEED*]	During a **climb**, entering a slower speed restriction of 260 kts for a waypoint will also change the speed at ANX. The current speed at ANX is the ECON speed of 303 kts., so the FMS changed the ANX speed to match the slower speed of FRANC. This along with the fact that a speed restriction greater than the TGT SPD in the CLB page will be accepted by the FMS, but the FMS will fly the slower ECON climb speed of 303 kts., means, this UM could be difficult to comply with in the FMS VNAV mode. A waypoint speed constraint is interpreted as a "cannot exceed" speed limit, which applies at the waypoint and all waypoints preceding the waypoint if the waypoint is in the climb phase, or all waypoints after it if the waypoint is in the descent phase [112]. Recommend executing this clearance with MCP speed intervention and not as an FMS VNAV procedure in a **climb**.

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td></td><td>To maintain current airspeed until reaching the AFTER PASSING [position], the crew should not enter a speed into the FMS until passing [position].</td></tr>
<tr><td>UM310: AT [LEVEL] MAINTAIN [SPEED]</td><td>The SPD TRANS and SPD RESTR on the FMS CLB page are restrictions to the CLB page TGT SPD. The FMS will maintain the slower of the TGT SPD, SPD TRANS, and SPD RESTR speeds when below TRANS and RESTR altitudes.
Climb:
SPD RESTR entry is used to maintain at or below the airspeed below the altitude. After climbing through the restriction altitude, the speed is set to the value in the VNAV CLB page or the next waypoint speed, whichever is lower.
If the crew wants to increase the airspeed above the speed set on the VNAV CLB page SEL SPD, then the SEL SPD value must be set to the increased airspeed.
Descent:
SPD RESTR entry is used to maintain airspeed below the set altitude in the SEL SPD. When the altitude is reached, the FMS enters the restriction. The speed restriction for descent is a LOWER speed than the speed displayed in the SEL SPD parameter contained in the DES page. Set up a scenario to descend out of FL350 with a 310 speed restriction at FL230, then a CHERI waypoint restriction of 320/16000. The FMS did not accelerate from 310 to 320 kts prior to CHERI because the crossing speed is greater than the speed restriction. 310 kts is maintained until the 10K ft. speed transition.
Note: the FMS did not get A/S to 250kts until 8800ft. A new waypoint restriction for CHERI is 300/15000A. FMS slowed from 310 to 300 kts 5nm prior to CHERI and maintained 300kts until 10K speed restriction. CLB or DES TGT SPD, together with the SPD REST, can be used to comply with this UM.

If the restriction is from a faster to a slower speed, then the SPD REST in the DES page can be used, but it is possible to miss the 10 & 250 restriction because there is only one SPD REST entry.
1.) Set the faster descent speed in the DES TGT SPD line.
2.) Set the UM speed/altitude restriction in the SPD REST line.
If the restriction is from a slower to a faster speed, then it is not possible to accelerate using the DES SPD REST line. The speed restriction of 250 kts below 10,000 ft can be exceeded. When the altitude is reached the FMS enters the restriction speed into the SEL SPD LSK

Climb:
If the restriction is from a slower to faster speed:
1.) Set slower speed and associated altitude in the SPD REST line.
2.) Set the faster speed as the CLB TGT SPD.
If the restriction is from a faster to a slower speed, then it is not possible to slow using the CLB SPD REST line.

Descent:
VNAV SPD TRANS is set to 250/10000 default value during initialization.

VNAV SPD RESTR is set by the crew to restrict the speed to a lower value than the TGT SPD or the SPD TRANS.

CLIMB mode:</td></tr>
</table>

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td></td><td>The speed restriction (SPD RESTR) on the CLB page allows the user to restrict the airspeed/Mach to a lower value than the airspeed/Mach contained in SEL SPD.</td></tr>
<tr><td>UM064: OFFSET [SPECIFIED DISTANCE] [DIRECTION] OF ROUTE</td><td>This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message, the crew must access the ATC LOG.

Offset is not only used for side-stepping weather, it is also used by ATC for RNAV routes as described in the Aeronautical Information Manual. Unpublished RNAV routes are direct routes, based on area navigation capability, between waypoints defined in terms of latitude/longitude coordinates, degree−distance fixes, or offsets from established routes/airways at a specified distance and direction. [AIM 5-3-4-3(c)]

If this UM is to be used to define an RNAV route based on an offset from an established route/airway, then the [route] will need to be defined in this UM. [7110.65, 4-4-i-4]

When clear of weather, the crew requests and ATC clears direct to next waypoint. The crew does not want to turn to get back on the original track and there is no need to return to the original track.

The OFFSET prompt displays on RTE page during climb, cruise and descent. An “OFFSET” message light is displayed by the CDU keypad. Some legs are not valid for offset:
• End of flight plan waypoint
• Discontinuity
• Beginning of approach transition
• Approach procedure
• DME arc
• Heading leg
• Holding pattern (except PPOS)
• Certain legs containing flyover waypoints
• Course change greater than 135 degrees
• Preplanned termination waypoint. [FCOM 11.42]

Unpublished RNAV routes are direct routes, based on area navigation capability, between waypoints defined in terms of latitude/longitude coordinates, degree−distance fixes, or offsets from established routes/airways at a specified distance and direction. Radar monitoring by ATC is required on all unpublished RNAV routes.
[AIM 5-3-4-3(c)]

The OFFSET prompt displays when the A/C is not on SID, STAR, or TRANSITION. As soon as A/C passes COU, the OFFSET prompt appears in ACT RTE 1 pages. [FCOM 11.40.17]

FANS1/A FMS Loadable Rules:
If the [direction] is specified as left or right and the [distanceoffset] is specified in nautical miles and is less than or equal to 99 NM, the FMS loads the data in a manner consistent with an offset entry on the RTE page.</td></tr>
</table>

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td>UM065: AT [POSITION] OFFSET [SPECIFIED DISTANCE] [DIRECTION] OF ROUTE</td><td>This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message, the crew must access the ATC LOG.

On legacy 744, the crew must remember to enter the beginning waypoint and ending waypoint for the offset. The crew may forget to do this. This will have to be handled through procedures and training for legacy types. However, on 733, the crew can program an offset at a downstream waypoint.

The crew should be advised by ATC when or where the offset will terminate.
Gotcha is that there is no way the crew can pre-enter prior to ENL. They have to make a mental note to WAIT until ENL then execute the clearance. If they get distracted then they may forget the clearance. AT [ENL] OFFSET [4nm] [right] OF ROUTE the crew needs to evaluate for RNP compliance as part of evaluation for all lateral and vertical maneuvers or route mods.</td></tr>
<tr><td>UM074: PROCEED DIRECT TO [POSITION]</td><td>This is a loadable clearance on the B787 and B777. The LOAD and CANCEL buttons are near each other. Should the crew mistakenly press the CANCEL button, then the ATC Windows blank and the message is not displayed. To retrieve the message the crew must access the ATC LOG.

In accordance with the AIM, when UM74 is issued by itself [position] it is considered the clearance limit. The AIM states: “When an aircraft is 3 minutes or less from a clearance limit and a clearance beyond the fix has not been received, the pilot is expected to start a speed reduction so that the aircraft will cross the fix, initially, at or below the maximum holding airspeed.” [FAA AIM 4-4-3-e-4, and 5-3-7-d]

Therefore, UM74 should be concatenated with holding instructions/EFC, full route clearance after the direct to waypoint or rest of route unchanged (UM289).

It may be possible that ‘loadable’ clearances bias the crew to ‘load and forget.’ SOP in manual loading where crew is more ‘in the loop’ is to clean up the LEGS page to remove discontinuities, etc. This should be crew action and not a systems action, since there are too many variables for the system to consider.

The “dir to” waypoint may be a new waypoint not in the LEGS page.

Selecting direct removes any offset

This type of clearance (UM74) can create route discontinuities (waypoint not in original flight plan). Training and procedures are needed to bias correct crew action. Cannot just ‘load and forget.’ Just as in manual entries, the crew must refer to the LEGS page (and map display) to ‘clean up’ any route discontinuities.</td></tr>
<tr><td>UM252: CROSS [POSITION] AT [RTATIMESEC] (OLD UM51)</td><td>Required Time of Arrival (RTA)
The “AT OR AFTER” crossing restriction is the easiest RTA restriction to obtain because it only requires delay crossing a waypoint. Increasing speed to “make up time” is much more difficult.
The FMS only adjusts speed to meet the RTA time restriction during cruise, not</td></tr>
</table>

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td></td><td>during climb or descent.
For a fixed Mach, a 2,000 foot change in altitude changes the TAS by approximately 5 kts. For example, if you hold .75 Mach, climbing from FL330 to FL370 will decrease TAS by 10 kts. Meeting RTA time constraints is much more difficult due to the varying winds at different altitudes and entering that information into the FMS.
A .01 change in Mach equals 5 to 6 kts. of TAS. To gain 1 minute over 1 hour, will require an increase from .76 Mach to .775 Mach. To gain 2 minutes - will require an increase from .76 Mach to approximately .79 mach. For a given Mach number above the IAS to Mach climb cross over point (narrow body FL 250, wide body FL 270), climbing decreases TAS, while descending increases TAS.
An RTA clearance has potential for long response times as crew evaluates whether aircraft performance can successfully comply with the required RTA time. The crew may want to send a STANDBY while the crew checks for RTA and to allow the a/c to accelerate to meet the RTA time

VNAV controls cruise speed to achieve a flight crew-specified arrival time at a specified waypoint. After the appropriate waypoint and RTA are input to the FMC, the FMC will compute a recommended takeoff time, speeds required to comply with the RTA, and progress information for the flight. If the RTA is not achievable, the RTA UNACHIEVABLE scratchpad message is displayed

RTA only operates in cruise. (747 FCOM pg.11.42.31)

FANS1/A FMS Load Rules
If the [position] is a fix in the active route, the FMS loads the specified [time] in a manner consistent with an RTA time entry on the RTA PROGRESS page.
The crew may want to send a STANDBY while the crew checks for RTA and to allow the a/c to accelerate to meet the RTA time. It takes about 40 seconds for the a/c to accelerate from ECON to the RTA required Mach. There may be some delay before the crew knows for sure if the a/c can make the RTA restriction.
It is important to enter winds for the route to improve the RTA prediction and to ensure the a/c can actually make the time restriction.</td></tr>
<tr><td>UM255: CROSS [POSITION] BETWEEN [RTATIMESEC] AND [RTATIMESEC]</td><td>No current FMS will accept user input to cross a waypoint between two times (i.e., time window). It is not likely that FMS OEMs are considering including this feature in an FMS soon.

The B737 FMS allows users to enter only one time with the following conditions:
No suffix = arrive at
A = arrive after
B = arrive before
The B747 FMS allows users to enter only one time with the following conditions:
No suffix = arrive at
A = arrive after
B = arrive before
The same action is accomplished using the “AT” time constraint, but with an expanded plus or minus tolerance, such as in a TIME ERROR TOLERANCE parameter in the FMS</td></tr>
</table>

<table>
<tr><th>UM</th><th>Compliance Factors</th></tr>
<tr><td></td><td>PERF LIMITS 2/2 page for the B-733 FMS. The parameter values are from 5 to 30 seconds, defaulting to 30 seconds.</td></tr>
<tr><td>UM258: CROSS [POSITION] AT OR AFTER [RTATIMSEC] AT [LEVEL]</td><td>The “AT OR AFTER” crossing restriction is the easiest RTA restriction to obtain because it only requires delay crossing a waypoint. Increasing speed to “make up time” is much more difficult.

The issue it that the FMS only adjusts speed to meet the RTA time restriction during cruise, not during climb or descent.

B733 – VNAV controls cruise speed to achieve a flight crew specified arrival time at a specified waypoint. (within 5 to 30 seconds)

B744, B777 – VNAV controls cruise speed to arrive at a specified waypoint within ± 30 seconds of a specified time. RTA operates only in cruise.

B787 – VNAV controls cruise speed to arrive at a specified waypoint within ± 6 seconds. [Ref. [9] Ch11, Sect 31]

A .01 change in Mach equals 5 to 6 kts. of TAS. To gain 1 minute over 1 hour, will require an increase from .76 Mach to .775 mach. To gain 2 minutes, will require an increase from .76 Mach to approximately .79 mach. For a given Mach number above the IAS to Mach climb cross over point (narrow body FL 250, wide body FL 270), climbing decreases TAS, while descending increases TAS.

For a fixed Mach, a 2,000 foot change in altitude changes the TAS by approximately 5 kts. For example, if you hold .75 Mach, climbing from FL330 to FL370 will decrease TAS by 10 kts. Meeting RTA time constraints is much more difficult due to the varying winds at different altitudes and entering that information into the FMS.

UM258 should not be used as a climb or descent clearance. A climb or descent clearance should include the phrase “AT AND MAINTAIN [level]” to reduce any confusion that the crew should level off at the clearance altitude.

Cruise:
If the A/C is at FL330, the PF cruise altitude is FL330 and the flight is planned to cross ENL at FL330, then this is the same as an RTA restriction.

Climb:
It is important that the waypoint is crossed at FL330. FL330 could be the final altitude, where a clearance should state “climb and maintain FL330,” so it is clear to the crew that this is a level-off altitude.
If FL330is not a level-off altitude and is an altitude the crew must climb through to their cleared cruise altitude (say FL370), then the crew must make sure that the altitude restriction and RTA are both attainable.

Descent:
This clearance restriction for a descent is almost never used in current-day operations, but it could be used in future tailored arrival operations to assist or verify FIM-S spacing requirements.</td></tr>
<tr><td>UM268: AT</td><td>This clearance can be a large clearance with a lot of routing. If the clearance message is</td></tr>
</table>

UM	Compliance Factors
[*POSITION*] CLEARED [*ROUTE CLEARANCE ENHANCED*]	too large for the AUX ATC window or the EICAS ATC Window, then "LARGE MESSAGE" will be displayed in the message window. The pilot will need to go to the COMM manager to see the entire message. On an MCDU configuration for CPDLC, the pilot must press the NEXT page key to cycle through the entire clearance. Also, a large clearance requires "Stepping through the flight plan" because the pilot cannot see the entire route on the ND. For very LARGE route modifications multiple pages are created on the COMM Manager. Crew must read the entire clearance. Crew will not get LOAD buttons until they are on the last page of the clearance.

4.6. Recommendations for Future Research

The following subsections list recommendations for future research based on this study.

4.6.1. Procedural

- Standardize rules for the use of DM2: "STANDBY." Frequency of use for STANDBY is still unknown and could inject unnecessary response delay into the system.
- Study procedures to reduce pilot response delay.
- Study limitations for the use of CPDLC with "legacy" FMS equipment. MCDU based systems have limitations on page size, page rows/columns and menu systems. In addition, CMU systems share the MCDU interface with other aircraft systems (FMS) and present challenges for alerting, pagination, and ability to easily show large clearances.
- Determine the role of voice communications in CPDLC operations especially surface (taxi environment), and terminal area operations.
- Investigate the common use of RTAs and their limitations. Current production FMSes cannot meet RTAs in climb or descent. RTA reliability can only be accomplished in the cruise segment.
- Investigate the design and use of CPDLC within the context of TBO, FIM-S, and Tailored Arrivals. CPDLC will become the primary means of communication with ATC. It is important that CPDLC procedures be designed.

4.6.2. System Design

- Investigate how VNAV can be improved to smoothly fly a SID, STAR, and TA to create a more comfortable ride for passengers.
- CPDLC messages are set to the lowest common denominator. Considering the vast differences in equipage and the ability of different airframes to accept messages, a common set of messages will work across all equipped airframes and still provide significant ATC system improvements AND still accomplish procedural goals such as TBO, FIM-S, CDA, and TA arrivals.
- Determine what pilot decision tools are most effective and practical to design and implement to aid the pilot in making quick and accurate decisions to meet performance based clearances.
- Investigate matching the UM requirements with FMS VNAV capability.
- Investigate the use of advanced software design such as artificial intelligence or agent systems.
- Explore the message set with other aircraft platforms (specifically Airbus, Embraer, Bombardier, etc.).
- Evaluate the use of CPDLC system inhibits for critical phases of flight (e.g., takeoff roll and initial climb out).
- The frequency of use and the time criticality of STANDBY are yet to be determined. In the oceanic or cruise environment, it is acceptable for STANDBY to be accessed via the COMM Manager. However, as CPDLC is implemented to other phases of flight, the time criticality and frequency of use may increase. It is recommended that STANDBY be easily accessible to the crew.

4.6.3. SC214 Message Set

- Assess the use and necessity of each UM, and determine the minimum/optimum number of UMs that are required for trajectory based operations.
- Determine an optimum number, then prioritize the UMs that are loadable into the FMS/MCP.
- Determine how to standardize loadable UMs for all FMS systems.
- Determine a standardized set of UM clearances to reduce ambiguity and pilot confusion.
- Determine and standardize rules for using UMs to build clearances.
- Investigate using UM wording and format after the current SID, STAR, and Approach charts.
- Investigate how large and complex of a UM can be sent before it causes excessive delay in clarification, negotiation and pilot error.

4.6.4. Training

- Determine how to improve the pilot familiarity and use of VNAV, and reduce pilot mode confusion.
- Investigate the best way to present an expanded section in the FCOM for CPDLC operations, procedures, and dealing with system faults.
- Design a QRH-type handbook for CPDLC.

4.6.5. Scenario Design

We recommend that these procedures for CPDLC design be thoroughly evaluated in a full simulation environment. The scenario route shown in Figure D-2, Appendix D is an excellent starting point for building a representative scenario for investigating many of the issues outlined in this section for future research.
The scenario should investigate flight deck issues such as:

- Pilot acceptance
- Crew coordination
- Use in various phases of flight
- High workload
- Integration with other procedures such as briefing, checklists, ACARS
- Procedure limitations. Do the procedures interfere with the work flow during approach?
- When will this procedure break down?
- Strategic changes. Can the TA route be quickly and easily changed for weather or traffic reasons?
- Effects of different flight deck equipment
- Procedure improvements
- Use of RTA during arrival
- Use of the " monitored approach" concept

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Appendix A – Definitions

Term	Definition
Actual Navigation Performance (ANP)	Actual navigation performance (ANP) is the FMC's estimate of the quality of its position determination. It is shown on POS SHIFT page 3/3 and on RTE LEGS pages. ANP represents the estimated maximum position error with 95% probability; that is, the FMC is 95% certain that the airplane's actual position lies within a circle with a radius of the ANP value around the FMC position. The lower the ANP value, the more confident the FMC is in its position estimate.
Air Traffic Clearance	Authorization for an aircraft to proceed under conditions specified by an air traffic control unit. **Note 1**: For convenience, the term "air traffic control clearance" is frequently abbreviated to "clearance." **Note 2**: The abbreviated term "clearance" may be prefixed by the words "taxi," "take-off," "departure," "en-route," "approach," or "landing" to indicate the particular portion of flight to which the air traffic control clearance relates. [ICAO] An authorization by air traffic control, for the purpose of preventing collision between known aircraft, for an aircraft to proceed under specified traffic conditions within controlled airspace. The pilot-in-command of an aircraft may not deviate from the provisions of a visual flight rules (VFR) or instrument flight rules (IFR) air traffic clearance except in an emergency or unless an amended clearance has been obtained. Additionally, the pilot may request a different clearance from that which has been issued by air traffic control (ATC) if information available to the pilot makes another course of action more practicable or if aircraft equipment limitations or company procedures forbid compliance with the clearance issued. Pilots may also request clarification or amendment, as appropriate, any time a clearance is not fully understood or is considered unacceptable because of safety of flight. Controllers should, in such instances and to the extent of operational practicality and safety, honor the pilot's request. 14 CFR Part 91.3(a) states: "The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft." THE PILOT IS RESPONSIBLE FOR REQUESTING AN AMENDED CLEARANCE if ATC issues a clearance that would cause a pilot to deviate from a rule or regulation, or in the pilot's opinion, would place the aircraft in jeopardy. [FAA AIM Pilot/Controller Glossary]
Air Traffic Control Instruction	Directives issued by air traffic control for the purpose of requiring flight crew to take a specific action. [ICAO]
Air traffic control service	A service provided for the purpose of preventing collisions: between aircraft and on the maneuvering area between aircraft and obstructions; and expediting and maintaining an orderly flow of air traffic
Air Traffic Management	The aggregation of the airborne functions and ground-based functions (air traffic services, airspace management, and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations.
Air Traffic Service	A generic term meaning, variously, flight information service, alerting service, air traffic advisory service, or air traffic control service (area control service, approach control service, or aerodrome control service).

Term	Definition
Air Traffic Services Unit (ATSU)	A generic term meaning, variously, ATC unit, flight information center, or ATC service area control services reporting office. In this document, ATSU refers to both human operators (e.g., Controllers) and automated systems (e.g., data processing systems) at an ATSU, unless specifically stated otherwise.
Alert	A method to draw the attention of the flight crew or controller, visually and/or aurally (e.g., arrival of a message, time-out).
ATS Message	A clearance or flight plan message. Included in this category are strategic messages associated with establishing the initial ATS clearance (user flight plan) and messages associated with revisions to the initial clearance. Also included in this category are tactical messages such as: (1) horizontal, vertical, or speed/time/delay instructions; (2) procedure-based instructions (instrument approach procedure); and (3) traffic and urgent advisories.
Clearance Limit	The fix, point, or location to which an aircraft is cleared when issued an air traffic clearance.
Conditional Waypoints	Conditional waypoints are automatically entered into a route as a result of selecting a procedure on a DEPARTURES or ARRIVALS page.
CPDLC Application	Controller-Pilot Data Link Communications application, providing the air-ground data communication between flight crew and controller for ATC services.
Communication Transaction	The cycle of ground- and air-initiated messages required for the full handshake that constitutes an information exchange between ground and airborne ATS system elements. The transaction cycles vary according to message types. For air traffic specialist-pilot communications, a typical cycle begins with message transmission and concludes with the return, to the sender, of an acknowledgment or reply from the intended receiver.
Current ATSU (C-ATSU)	The ATSU that can exchange ATC communications messages with an aircraft.
Current Data Authority	The designated ground system through which a CPDLC dialogue between a flight crew and a controller currently responsible for the flight is permitted to take place.
Data Comm	Data Link Communications: Includes CPDLC, TIS-B, and FIS-B.
Data Link Application	A data link application facilitates specific air traffic management (ATM) operational functionalities using specific data link technology.
Data link service	A data link service is a set of ATM-related dialogues, both system and manually supported, within a data link application that have a clearly defined operational goal. (In this context DLIC, ACL, ACM, and AMC)
Dialable	Dialable refers to the software design that provides visual feedback to the pilot that a value dialed in the MCP in response to a clearance UM matches the value in the UM. When the altitude, heading, or speed value dialed in the MCP matches the altitude, heading, or speed value displayed in the UM located in the AUX display for 787, or in the ECAS display for 777, the UM display value turns from white to green. This color change gives positive feedback to the pilot that he entered the correct clearance value in the MCP.
DM Time	The time it takes for the pilot to find the DM and then send it.

Term	Definition
Expiration Timer-Initiator	Timer used by a sending system to detect the absence of an operational response from the remote system in an acceptable time period. The timer-sender starts when the message is released by the initiator. It ends when an indication of the receipt of the operational reply is provided to the initiator.
Expiration Timer-Responder	Timer used by a receiving system to detect the absence of a response to a received message in an acceptable time period. The timer-responder starts when an indication of the receipt of the message is provided to the responder. It ends when the operational reply is released by the responder.
Flight Interval Management – Spacing (FIM-S)	An ADS-B-based concept to precisely manage intervals between aircraft whose trajectories are common or merging through flight deck technology.
Flight Information Message	An informational message that does not imply any change in operating behavior on the part of the pilot or the controller. Information messages are generally not time-critical. Included in this category are routine weather observations and forecasts, reports on the status of facilities and equipment, and routine position reports.
Flight plan	Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft. A flight plan can take several forms, such as: Current Flight Plan (CPL). The flight plan, including changes, if any, brought about by subsequent clearances. **Note:** *When the word "message" is used as a suffix to this term, it denotes the content and format of the current flight plan data sent from one unit to another.*
Filed flight plan (PFL).	The flight plan as filed with an ATS unit by the flight crew or a designated representative, without any subsequent changes. **Note:** *When the word "message" is used as a suffix to this term, it denotes the content and format of the filed flight plan data as transmitted.*
LACK Timer Technical	Response timer used by a sending system to detect the absence of an expected LACK response in an acceptable period of time.
Latency Time Check	A time check that is activated by a receiving system when the uplinked CPDLC message is received after the allowed limit. The system indicates that the CPDLC message has become invalid for treatment.
Loadable	Loadable refers to uplink message information entered by datalink avionics into the FMC modified flight plan, or to uplink values displayed to the pilot on the MCP that meet certain logical disposition criteria. The aircraft will not navigate using this information until the pilot executes the modified flight plan to make it the active flight plan in the FMS. [heading] and [track] data are also displayable on the MCP. The [altimeter] setting is displayed on the PFD; VHF [frequency] is displayed on RMP; [speed] on MCP, etc. Loadable UMs are defined as uplink messages containing ATC clearance information that can be automatically loaded by the datalink avionics into the FMS.
Menu Page	A single menu containing formatted text for title, labels, and variable names and input placeholders for input variables.
Menu Logic	The software programming logic behind the menu system to improve the usability of data entry, menu navigation, data entry support, and error recognition.
Menu System	Defined as the combination of both the formatted menu pages and the programmed logic (menu logic) to control the pages. Menu System = Menu Pages + Menu Logic

Term	Definition
Next Data Authority	The ground system so designated by the current data authority through which an onward transfer of communications and control can take place. [PANS-ATM]
Required Navigation Performance (RNP)	A statement of the navigational performance necessary for operation within a defined airspace. The following terms are commonly associated with RNP: (a.) - RNP Level or Type (RNP-X). A value, in nautical miles (NM), from the intended horizontal position within which an aircraft would be at least 95% of the total flying time. (b.) - RNP Airspace. A generic term designating airspace, route(s), leg(s), operation(s), or procedure(s) where minimum required navigational performance (RNP) has been established. (c.) - Actual Navigation Performance (ANP). A measure of the current estimated navigational performance. Also referred to as Estimated Position Error (EPE). (d.) - Estimated Position Error (EPE). A measure of the current estimated navigational performance. Also referred to as Actual Navigation Performance (ANP). (e.) - Lateral Navigation (LNAV). A function of RNAV equipment that calculates, displays, and provides lateral guidance to a profile or path. (f.) - Vertical Navigation (VNAV). A function of RNAV equipment that calculates, displays, and provides vertical guidance to a profile or path.
Speed Schedule	The calculated or manually entered speeds the FMS is scheduled to use for the climb, cruise, and descent when considering schedule requirements, ATC clearance, fuel, and operating costs. Speed schedule includes: • Initial cruise speed (at top of climb (TOC)); • Last cruise speed (at top of descent (TOD)); • Descent speed.
Standardization	1.) Commonalty of cockpit hardware and procedures within and across fleets. 2.) Quality control of pilot performance in adherence to procedures and regulation.
Supplemental means of communication:	Communication capability that is not required for the intended operation but, if available, can be used as an alternative to the primary means.
Tailored Arrival (TA)	A tailored arrival specifies altitude and spacing targets for aircraft. It allows a continuous descent at low engine power. • It is tailored to: - Avoid conflicts - Meet traffic-flow constraints - Avoid restricted airspace, weather, terrain - Accommodate specific aircraft constraints • It is given as a single clearance well prior to TOD and is coordinated across airspace/facility boundaries. A tailored arrival clearance is loaded into and flown using aircraft FMS and is delivered by data-link for minimal workload.
Task Time	For this research, task time is the time the crew requires to complete the task required by an uplink message clearance from ATC. The task starts at the time the crew is alerted and ends at the time the crew acts on the clearance and responds to ATC with a downlink message.
Trajectory-Based Operations (TBO)	The use of 4D-trajectories as the basis for planning and executing all flight operations supported by the air navigation service provider.
Transferring ATS Unit (T-ATSU)	The ATS unit that is transferring control responsibility of a flight.

Term	Definition
UM Dimension	A CPDLC message can be sent to a crew as either a single UM or as a concatenated UM.
UM Time	Time from when the ATC Controller sends a UM until the controller receives the pilot DM response to the UM.
Variable	Information or data contained in a DM or UM
Variable Type	A description or category of the variable that must be included with the value (characters or numerical value) of the variable.

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Appendix B – Acronyms

Acronym	Definition
4D Data Link	Trajectory-based Data Link
AC	Advisory Circular
ACARS	Aircraft Comm, Addressing and Reporting System
ACC	Area Control Center
ACL	ATC Clearances – data link service – messages
ACM	ATC Communication Management
ADS-B	Automatic Dependent Surveillance - Broadcast
ADS-C	Automatic Dependent Surveillance - Contract
AF	Airway Facilities
AFCS	Auto Flight Control System
AFDS	Autopilot Field Director System; AutoFlight Director System
AFDX	Avionics Full-DupleX network
AFN	ATS Facilities Notification
AIC	Aeronautical Information Circular
AIM	Aeronautical (Airman's) Information Manual
AIP	Aeronautical Information Publication
AMC	ATC Microphone Check – data link service
ANP	Actual Navigation Performance
ANSI	American National Standards Institute
ANSP	Air Navigation Service Provider
AOC	Airline Operational Communication
ARINC	Aeronautical Radio, Inc
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATIS	Automatic Terminal Information System
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
ATSU	Air Traffic Services Unit
B733	Boeing 737-300
B744	Boeing 747-400
B748	Boeing 747-800
B777	Boeing 777
B787	Boeing 787
B-RNAV	Basic Area Navigation
C-ATSU	Current Air Traffic Services Unit
CDA	Current Data Authority
CDA	Constant Descent Approach
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit
CHG	ICAO defined Change message
CMF	Communication Management Function
CMU	Communications Management Unit
CNS	Communication, Navigation, and Surveillance
CPDLC	Controller-Pilot Data Link Communication
CPL	Current Flight Plan
CPT	Cockpit Procedures Training
CRI	Canarsie VOR; Certification Review Item
CRM	Crew Resource Management
D-ATIS	Data link Automatic Terminal Information Service
D-ATSU	Downstream ATSU
D-TAXI	Data link Taxi Service
DCDU	Data Communication Display Unit
DCL	Departure Clearance
DM	Downlink Message
EFC	Expect Further Clearance
EICAS	Engine Indication and Crew Alerting System
EPE	Estimated Position Error
ER	En Route
ET	Expiration Time
FAF	Final Approach Fix
FANS	Future Air Navigation System - see CNS/ATM
FCOM	Flight Crew Operating Manual
FDMS	Flight Deck Merging and Spacing
FIM-S	Flight Interval Management – Spacing
FIR	Flight Information Region
FIS	Flight Information Service
FL	Flight Level
FMC	Flight Management Computer
FMF	Flight Management Function
FMS	Flight Management System
FO	First Officer
FSF	Flight Safety Foundation
GIM	Ground-based Interval Management
HCI	Human Computer Interface
HF	Human Factors
HFDL	High Frequency Data Link
HMI	Human Machine Interface
HSD	Horizontal Situation Display
HSI	Heading Situation Indicator
H/W	Hardware
IAF	Initial Approach Fix
IAP	Instrument Approach Procedures
IAW	In Accordance With

Acronym	Definition
IC	Initial Contact
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
ISA	Instantaneous Self-Assessment
KMIA	Miami International Airport
LACK	Logical ACKnowledgment
LAHSO	Land and Hold Short
LNAV	Lateral Navigation Performance
LOFT	Line Oriented Flight Training
LOSA	Line Operations Safety Audits
LSK	Line Select Key
MAP mode	Moving map mode
MCDU	Multipurpose Control and Display Unit
MCP	Mode Control Panel
MEL	Minimum Equipment List
MFD	Multi Function Display
MIN	Message Identification Number
MRN	Message Reference Number
MSG	Message
MSL	Mean Sea Level
NAS	National Airspace System
NDA	Next Data Authority
NFP	Non-Flying Pilot
NM	Nautical Mile
OCL	Oceanic Clearance
OpSpecs	Operation Specifications
OTA	Other Transaction Authority
PBD	Place, Bearing, Distance
PF	Pilot Flying
PDC	Pre-Departure Checklist; Pre-Departure Clearances
PFL	Filed Flight Plan
PFD	Primary Flight Display
PIC	Pilot in Command
PIREP	Pilot Report
PM	Pilot Monitoring
PNF	Pilot Not Flying
POI	Principle Operations Inspector
PSR	Primary Surveillance Radar
QRH	*Quick Reference Handbook*
R-ATSU	Receiving Air Traffic Service Unit
R-Sector	Receiving Sector
REQ	Required Action
RNAV	Area Navigation
RNP	Required Navigation Performance
R/T	Radio-Telephony; Receive/Transmit
RTA	Required Time of Arrival

Acronym	Definition
SA	Situational Awareness
SATCOM	Satellite Communication
SDU	Satellite Data Unit
SID	Standard Instrument Departure
SOP	Standard Operating Procedures
SP	Subject Pilot or Scratchpad
SSR	Secondary Surveillance Radar
STAR	Standard Terminal Arrival Route
TA	Tailored Arrival
T-ATSU	Transferring Air Traffic Service Unit
TAF	Terminal Aerodrome Forecasts
TBO	Trajectory Based Operations
TCA	Terminal Control Area
TLX	Task Load Index
T/O	Takeoff
TOC	Top of Climb
TOD	Top of Descent
TOGA	TakeOff Go Around
UM	Uplink Message
UTC	Coordinated Universal Time
VCI	Voice Contact Instruction
VFR	Visual Flight Rules
VHF	Very High Frequency
VNAV	Vertical Navigation
VOR	VHF Omnidirectional Range
VOX	Voice Operated eXchange
WILCO	Will Comply
WP	Waypoint
ZMA	Miami Center (ARTCC)
ZNY	New York Center (ARTCC)

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C-2: Selected Reference Synopsis

Table C-1. Government Reference Documents

Ref.	Document	Document Description	Date
301	DTFAWA-10-A-80003	Data Communications Avionics Government/Industry Other Transaction Agreement	Sep 2009
302	ASN 1 SPR-H Part3 CPDLC	Data Communications Safety and Performance Requirements (Input for Validation)	3 Feb 2010
303	Order JO 710.65S	FAA Air Traffic Control	14 Feb 2008
304	DOT/FAA/TC-07/11	A Human Factors Design Standard	May 2007
305	AC 120-70A	Operational Authorization Process for Use in Data Link Communications Systems	29 Dec 2005
306	AC 20-140A	Guidelines for Design Approval of Aircraft Data Com Systems	7 Apr 2010
307	DOT/FAA/AR-99/52	DOT-VNTSC-FAA-98-5, Guidelines for the Use of Color in ATC Displays. Cardosi, K., & Hannon, D., 1999	1999

Table C-2. Industry Reference Documents

Ref.	Document	Document Description	Date
401	ICAO Doc 4444	Rules of the Air and Air Traffic Services	1996
402	ICAO Doc 9694	Manual of Air Traffic Services Data Link Applications	1999
403	RTCA/DO-219	Minimum Operational Performance Standards for ATC Two-Way Data Link Communications.	27 Aug 1993
404	RTCA/DO-238	Human Engineering Guidance for Data Link Systems	1997
405	RTCA/DO-256	Minimum Human Factors Standards for Air Traffic Services Provided via Data Communications Utilizing the ATN, Builds I and IA	20 Jun 2000
406	RTCA/DO-280B	Interoperability Requirements for ATN Baseline 1 (INTEROP ATN B1)	2007
407	SAE ARP 4791	Human Engineering Recommendations for Data Link Systems	Feb 2008
408	SAE ARD 50027	Human Engineering Issues for Data Link Systems	1991
409	ICAO Doc 9705	Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN)	1999

Ref.	Document	Document Description	Date
410	Link 2000+ Flt Crew	Flight Crew Data Link Operational Guidance for Link2000+ Services	30 Jun 2009
411	Link 2000+ ATC	ATC Data Link Operational Guidance for LINK2000+ Services	30 Jun 2009
412	United B777 Flight Manual	Chapter 13 Additional Procedures, Section 40 Communications; CNS Enroute Operating Guide	26 Jun 2009
413	MITRE Tech. Report MTR90W 215	Blassic, E., & Kerns, K., Controller Evaluation of Terminal Data Link Services: Study, McLean, VA: The MITRE Corporation	1990
414	SAE Tech. Paper 871764	Groce, J.L., & Boucek, G.P., Air Transport Crew Tasking in an ATC Data Link Environment, Warrendale, PA: SAE International.	1987
415	SAE Tech. Paper 922022	Hahn, E.C., & Hansman, R.J., Jr., Experimental Studies on the Effect of Automation on Pilot Situational Awareness in the Datalink ATC Environment, Warrendale, PA: SAE International	1992
416	RTCA Paper No. 754-92/SC169-194	Human Factors Task Force, Human Factors Requirements for Data Link., Washington, D.C.: RTCA	1992
417	SAE Tech. Paper 901887	Kerns, K., Data Link Communications Between Controllers and Pilots: State of the Knowledge, Warrendale, PA: SAE International	1990
418	IJAP	Kerns, K., Data-Link Communication Between Controllers and Pilots: A Review and Synthesis of the Simulation Literature, The International Journal of Aviation Psychology, 1(3): 181-204.	1991
419	MITRE Paper MP-94W98	Kerns, K., Human Factors in ATC/Flight Deck Integration: Implications of Data Link Simulation Research, McLean, VA: The MITRE Corporation	1994
420	TRB 2005	Baik, H, & Trani, A.A., Measuring Benefits of Controller-Pilot Data-Link Communication (CPDLC) System in an Airport Area Using a Microscopic Simulation Model	2005
423	DOT/FAAIRCRAFTT-TN95/62	Rehmann, A.J., Airborne Data Link Study Report	1996

Ref.	Document	Document Description	Date
424	DOT/FAAIRCRAFTT-TN97/6	Human Factors Recommendations for Airborne Controller-Pilot Data Link Communications (CPDLC) Systems: A Synthesis of Research Results and Literature	Jun 1997
425	ICAO Doc 8400	ICAO Abbreviations and Codes (6th Edition)	2007
426	DOT/FAA CT-92/2, I	Talota, N.J., et al. Controller Evaluation of Initial Data Link Terminal Air Traffic Control Services: Mini-Study 2, Volume I	1992
427	DOT/FAA CT-92/18, I	Talota, N.J., et al. (1992b). Controller Evaluation of Initial Data Link Terminal Air Traffic Control Services: Mini-Study 3, Volume I	1992

Table C-3. Honeywell Reference Documents

Ref.	Document	Document Description	Date
501	PS600000 52800	Primus EPIC CPDLC for Embraer	Sep 2009
502	170AVD09	Communication Management Function System Description Report	03 Oct 2006
503	998-6178-210	CMU ATC HMI SRD	4 Nov 2009
504	060-4515-001-A	Link 2000 Mk2 Pilot Guide	2006
505	DTFAWA-10-A-80003-MYY-01-ZZ	Crew Information Requirements Document for CPDLC	18 Dec 2009
505	DTFAWA-10-A-80003-M2C-02-10	CPDLC Concept Prototype Report	12 Feb 2010

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Appendix D – ZMA and MIA TRACON Observation

D-1: Miami Center (ZMA)

Below is part of the High Altitude Enroute chart for the Northeast sectors of Miami Center (ZMA). The eastern ZMA sector boundary is highlighted with the yellow line. The TA begins at SUMRS intersection on the ZMA boundary, passes through ZMA, and enters Miami TRACON airspace northeast of HILEY intersection. The TA route generally follows the A699 high altitude route.

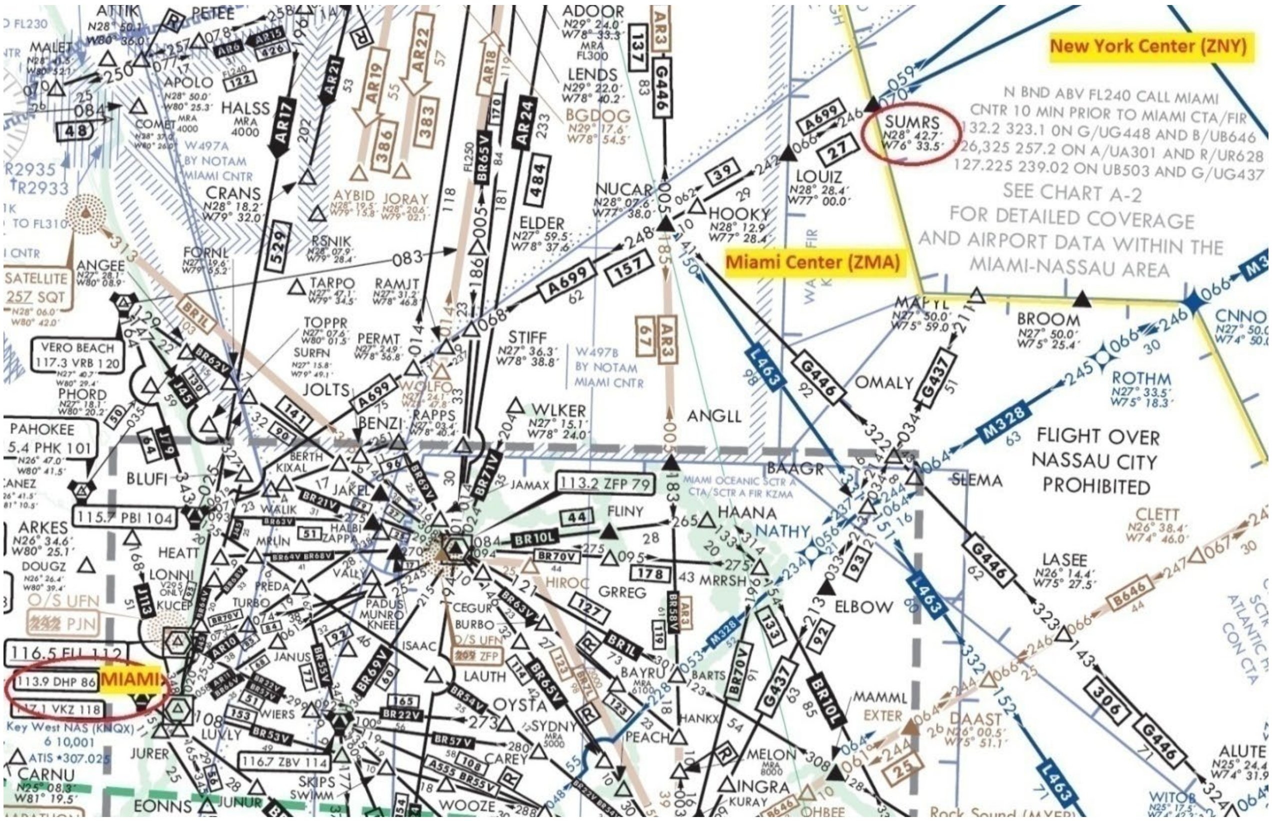


Figure D-1: Miami Center Eastern Sector

The TA route is modified from A699 to fly further westbound away from the north-south traffic along the coast of Florida. This is to minimize the conflict of the TA aircraft with the north-south arrival and departure traffic from the South Florida area.

The sequence of events for the TA aircraft in ZMA airspace:

- Because the TA is a non-published procedure, the crew must request the TA from ZNY, and it must be requested using CPDLC. The TA is requested prior to entering ZMA airspace. Other communication with ZNY is by HF voice radio.
- TA aircraft are cleared by New York Center (ZNY) for either the Florida 8 or Florida 9 Tailored Arrival. Florida 8 TA is for Runway 8R and Florida 9 is for Runway 9.
- ZNY instructs the TA aircraft to contact ZMA at SUMRS.
- The TA aircraft crosses the ZMA boundary at SUMRS intersection (top right corner of the chart) at cruise altitude.
- ZNY contacts ZMA via land line to hand off the TA aircraft.
- The crew contacts ZMA via VHF voice and informs the controller that they are on the Florida 8/9 TA.

- The aircraft is still about 10 minutes to top of descent (TOD). The crew will usually be instructed to maintain cruise altitude because the controller has to ensure that aircraft passing through the TA route will have enough separation with the TA aircraft. The controller may request the crew to report 3 minutes prior to TOD. This technique helps the controller identify possible conflict traffic prior to descent.
- When satisfied that sufficient separation is assured, the controller clears the crew to descend via the TA and to "*cross HILEY at and maintain 14,000 feet*." If the TA is flown as planned, this is the last time ZMA talks to the crew until handoff to TRACON.
- The HILEY intersection is shared with the TA aircraft and with other southbound traffic using the HILEY2 Arrival. The 14,000-foot crossing restriction at HILEY is called a "paper stop." The intent is not to stop the TA descent at 14,000 but to ensure that aircraft arriving from the north on the HILEY2 STAR do not conflict with the TA aircraft arriving from the northeast (see Figure D-1). As the TA aircraft approaches HILEY intersection and there are no conflicts from other arrival aircraft, the controller clears the crew for the remainder of the TA for the ILS RW 8R/9.
- As it flies its route from SUMRS to just northeast of HILEY, the controller must vector other aircraft around, over, or under the TA aircraft. There are two crossing restrictions for the TA aircraft: one at or above FL340 and another at or above FL240.
- For the TA to be effective, the TOD and descent path are calculated and controlled by the aircraft's FMS. As a result, the controller does not have direct control of the aircraft's altitude and must estimate or guess its projected altitude. This increases the controller's workload and requires extra vigilance because the same separation is required, but with less control over the aircraft. Therefore, controllers must add additional separation due to less precise prediction of aircraft location.
- There are three controllers that handle the TA aircraft within ZMA.

Below are some of the notes and issues associated with controlling TA aircraft in the current ATC environment:

- All separation is performed using the radar screen and a few software tools.
- All aircraft within the controller's assigned sector(s) must be continuously scanned to "manually" keep the required separation between aircraft using only documented procedures, judgment, experience, and skill. There are no software tools that provide the controller with heading or altitude recommendations to assist separation.
- For metering traffic into Fort Lauderdale (KFLL), a software tool has been implemented to adjust the amount of time needed for each aircraft to be sequenced into KFLL. KMIA does not need to be metered because there are sufficient runways at KMIA to handle normal traffic.
- Thunderstorms are prevalent in the summer months and are usually fast moving. When thunderstorms hit the South Florida area, they are usually handled by vectoring and slowing aircraft, as well as putting aircraft in holding patterns. You can almost always count on a short hold due to the speed of the thunderstorms.
- The second of the three controllers (Pam) had the TA aircraft for about 20 minutes. The level of scanning and concentration increased with the TA aircraft in her sector. Pam did an exceptional job predicting the separation of the other aircraft with the TA aircraft. In one case, Pam used a screen tool to project the route based on the current heading of a potential conflicting aircraft at the bottom of the screen heading north. The difficulty is to project 10 minutes in the future the positions of each conflicting aircraft while continuously scanning all other aircraft. Experience and skill are required to identify conflicts sufficiently far enough in advance.

Comments about TA in ZMA:

- ZMA and MIA TRACON do not use CPDLC.
- It goes against all controllers' training to clear an aircraft to climb to a higher altitude when there is another aircraft above descending to a lower altitude in the same area. Without the 14,000-foot "paper stop" restriction at HILEY, the controller can clear a TA aircraft from cruise altitude of FL390 to 3,000 feet to intercept the ILS.

D-2: Miami TRACON

Control and separation at TRACON is all done manually. TRACON has limited the number of TA aircraft it can control at one time to one. This is due to the added workload required by a single TA aircraft. Controlling the TA aircraft is not the issue. It is the other aircraft the controller must “get out of the way” (i.e., separate) of the TA aircraft because essentially the controller does not have direct control over the TA aircraft. If the controller issues a heading or speed instruction, the TA is ended and the remainder of the approach is done using conventional vectors and altitude clearances.

The TA Arrival is not a published approach; as a result, the crew must request the TA prior to entering ZMA (Miami Center) airspace. The TA route inside TRACON airspace begins northeast of the HILEY waypoint in the STAR. The TA route is a modification of this STAR that was agreed upon by Boeing, MIA TRACON, and several participating airlines. The TA arrival (called FLORIDA 8 for runway 8 and FLORIDA 9 for runway 9) is a modification of the HILEY STAR with numerous “AT OR ABOVE” altitude crossing restrictions. Both Boeing and the participating airlines consider TA procedure to be proprietary and will not divulge the details of the approach. A gross description of the arrival is outlined in Figure D-2.

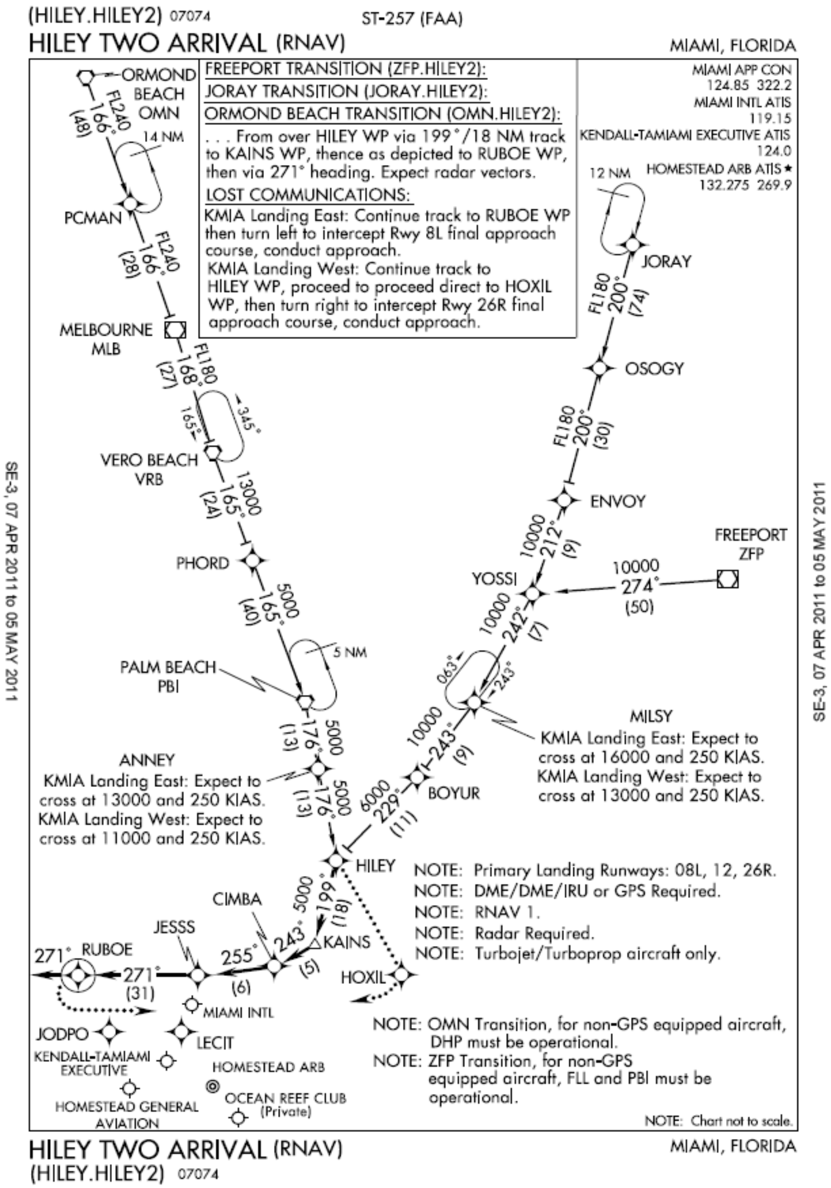
Below are some of the issues with a TA aircraft:

- Keeping the TA aircraft from running over slower traffic.
- Watching the TA aircraft to see if it will make the altitude restrictions or will turn at the required waypoints. The controllers still do not have the confidence that the TA aircraft will actually follow the flight path.
- Airlines do not publish the exact procedures they will follow, but from experience they know that the TA aircraft will pass the downwind-to-base waypoint at 210 kts.
- The controllers do not have much experience with TAs because they seldom see a TA. The flight crew must request a TA from New York Center prior to reaching SUMRS.

We observed only one TA being performed. Of the four candidate aircraft—two Lufthansa, an American, and an Air France—only the Air France flew the TA. The controller had to vector another aircraft Tampa Cargo B767 while it was descending for a visual approach to RW9. Cargo aircraft typically use the south runway because it is much closer to the cargo parking. The controller saw a potential conflict between Tampa and AF680 when AF was approaching the downwind-to-base waypoint. While AF was turning base, the controller turned Tampa west and then back east on downwind to increase the spacing between Tampa and AF. The controller turned Tampa six miles behind AF to follow AF on final to RW9. As it turned out, the initial spacing between Tampa and AF was fine, but to the controller, the faster speed prior to the downwind-to-base turn gave the impression that there would be a conflict between the two aircraft. In fact, if the controller would have allowed the two aircraft to fly their approaches as planned, then Tampa would have been five or more miles ahead of AF on final. The time and fuel saved by AF was more than wasted by the Tampa vectoring, so the TA was a net loss.

So mixing a TA aircraft with the conventional vector controlling/separation creates an added workload. This begs the question: What percentage of TA and “conventional vectoring” aircraft is needed to REDUCE the controller workload?

The controllers have to judge 10 minutes ahead of the TA aircraft to avoid conflicts between the TA aircraft and all other aircraft, with the restriction that the controller cannot control the TA aircraft. The result is overcompensation of separation.



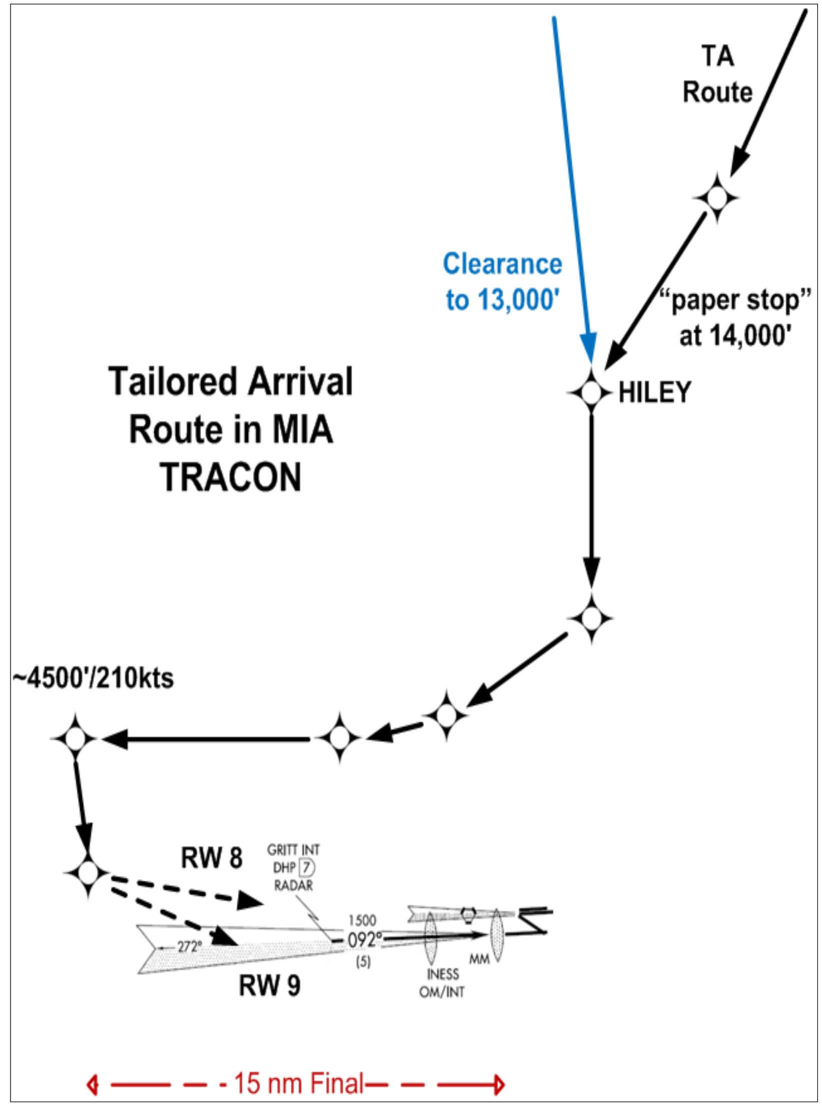


Figure D-2: Florida 8 / 9 Tailored Arrival

Appendix E – NASA ASRS Lessons Learned

This ASRS Data Search was aimed at identifying and understanding the operational problems with a new the Data Link and FANS-1 communication technology.

The following information is compiled from Data Link search of the NASA Aviation Safety Reporting System database. The reports are divided into the following categories:

- **Misread Clearance** – Problems associated with reading or understanding data link clearances
- **ATC Uplink Problem** – Problems with ATC Data Link equipment, procedures, or clearances
- **Procedure Problem** – Problems or perceived problems with the operational procedures associated with the data link
- **Equipment Problem** – Problems with the aircraft using the data link
- **Emergencies** – Using the data link in an emergency situation
- **CPDLC Would Have Helped** – Problems crews had and commented that the data link would have averted the problem

E-1: Misread Clearance

ACN	DESCRIPTION	ISSUE
795258	Crew did not see the "**AT**" in the following clearance and climbed early: *'MAINTAIN FL340, **AT** XC00Z CLB TO AND MAINTAIN FL370, RPT LEVEL FL370'*	Crew focused on FL370, which was what they anticipated.
772447	Crew had a complicated clearance out of PVD. Crew complained aircraft does not have a printer to look at the clearance in a better format and to reference the clearance.	A printer is a useful tool to look at the information in a familiar format. A standard clearance format is necessary.
516897	Crew requested climb to FL370. In the ATC response, it was denied and a clearance was given to climb to FL360. The crew missed the climb to FL360.	Easy to fixate on what you are looking for and miss the rest. Send the clearance in two parts or in clearer/simpler format.
504740	Pilot requested FL370 and in free text asked for block altitude FL350-370. Pilot rejected a response clearance to climb to FL370. Pilot stayed at FL350.	ATC expected pilot to accept the clearance to FL370. If UNABLE sent to ATC, then it may be good to state pilot's intentions. (i.e., "UNABLE FL370 DUE TO AIRCRAFT PERFORMANCE, WILL MAINTAIN FL350").
439440	Relieving pilot did not understand the cleared block altitude limits. CPDLC was OTS, using HF for comms.	
426722	Crew missed the time requirement to begin climb. Relieving crew found the problem after relieving the main crew.	Conditional clearance missed.
426352	Crew requested climb and received: **"AT** XX08 CLB TO AND MAINTAIN FL350." They missed the time condition (XX08).	Conditional clearance missed.
426098	Crew climbed 26 min early because they misread the data link clearance – did not see the "AT" time.	Conditional clearance missed.

413149	FO misread ATC inquiry for higher alt as a clearance for higher altitude.	The ACCEPT & REJECT LSK responses for an ATC inquiry are the same as for a clearance.
412831	Crew cleared block alt FL310-FL330, AT FL320 AT APPROX XA00Z, received clearance: *'CLB TO FL330 BY XB15Z RPT LEVEL FL330.'* Crew checked clearance and aircraft alt and missed that the clearance was for 330 and the aircraft was at 320.	Although it was a conditional clearance, the crew overlooked the altitude discrepancy.
411751	Crew received clearance: *'AT LONGITUDE XXX, CLB AND MAINTAIN FL330, SQUAWK XXXX.'* Crew did not know whether to Squawk now or at Long XXX.	Conditional clearance is confusing. Order of the items in the clearance makes a difference.
363370	Crew received by voice: *'EXPECT FL330 WHEN CLR.'* Crew began descent early.	The CPDLC reply to an 'EXPECT….' UM should not have ACCEPT or REJECT as pilot responses.
359619	Crew received ATC DLC clearance: *XA38Z ATC UPLINK/CROSS 0100S AT AND MAINTAIN FL350/RPT REACHING FL350*. When the crew printed and read the message, they read 10 DEGS S NOT 01 (ONE) DEG S.	Crew misread Lat/Lon numbers.
356629	Crew received a clearance that changed their route. They compared old and new flight plans. Replaced GIPER with KENUK, but "SIMILAR APPEARANCE OF 5015N AND 5115N, THE CHANGE FROM 5115N TO 5015N WAS OVERLOOKED."	Crew missed a Lat/Lon change in the clearance.
344041	Crew requested higher. ATC gave DLC clearance: 'CLRED DIRECT 1510N 150W, DIRECT 12N 156W, DIRECT 05N 164W, AT 150W CLB AND MAINTAIN FL350, RPT REACHING FL350. Crew missed the AT longitude condition to begin climb.	Conditional clearance missed.
242150	Crew missed change in clearance in flight plan.	Crew did not see the amendment letter after the flight plan number.

Lessons learned:

1.) Conditional clearances are easy to miss. Although conditional clearances may also be misunderstood or forgotten in voice communications, the readback requires an opportunity for the controller to emphasize the conditional restriction and make is less likely that an error will occur.
2.) Crews ask for and are eager to receive a climb clearance. They are usually not expecting a conditional climb clearance and are vulnerable to misreading a clearance.
3.) Too much and poorly formatted information in a clearance can cause the pilot to overlook an important feature of the clearance.
4.) Format the conditional clearance to be obvious to the pilot.
5.) Mixed-font formats make the short word '**at**' hard to notice.
6.) When ATC asks a question or gives an 'EXPECT' message, the response displayed to the pilot should not be ACCEPT or REJECT.
7.) Highlight changes to flight plans to make it easy to see the changes between the old and new flight plans.
8.) Multi-page messages are difficult to read and easy to miss.

E-2: Emergency

ACN	DESCRIPTION	ISSUE
836389	ATC would not permit track deviation for weather avoidance. Crew informed by Center that right deviations might be available in about 10 minutes. Captain declared emergency and diverted off an oceanic track at FL360.	The urgency of the diversion is lost when using CPDLC.
814431	Loss of crew oxygen and SOP required immediate descent. Crew had delay getting a clearance using CPDLC. Called HF and received a clearance	Delay using CPDLC.
810319	Crew experienced smoke in the aircraft. Declared an ADS Emergency and received a CPDLC clearance.	Use of CPDLC for emergency OK.
801070	Crew could not get a clearance for weather deviation from RJJJ. Captain declared emergency on data link using free text.	Free text useful here. Urgency of deviation was not understood by ATC.
771994	Crew required deviation due to mechanical problems. It took 8 minutes to get clearance to divert using CPDLC.	Longer than necessary to divert.
766365	Crew had smoke in cockpit. Use of CPDLC to declare emergency was timely.	Use of CPDLC for emergency OK.
753323	Crew requested diversion due to weather. Delay in getting clearance. Captain declared emergency.	The urgency of the diversion can be lost when using CPDLC.
744431	Crew attempted a re-route for volcanic ash with Tokyo ATC via CPDLC. Told crew to get clearance from SFO. SFO re-routed.	
721306	Captain declared emergency after ATC denied deviation for weather avoidance.	The urgency of the diversion can be lost when using CPDLC.
718887	Crew attempted re-route via CPDLC and HF due to equip-ment failure. Crew had company dispatcher work re-route. Crew could not contact ATC on CPDLC and HF. Captain declared emergency.	Not in ATC contact.
701094	Crew could not get timely clearance from Tokyo for weather deviation. Captain declared emergency.	The urgency of the diversion can be lost when using CPDLC.
700557	A B777 CREW IN OCEANIC AIRSPACE USED CAPT'S EMER AUTH TO DEVIATE AROUND TSTMS WHEN THE DATA LINK CLRNC AUTHORIZING THE DEV WAS LATE ARRIVING.	Delay in clearance.
594166	B747-400 CREW WAS REQUIRED TO DECLARE AN EMER TO AVOID FLT INTO A TSTM CELL IN PACIFIC INTL AIRSPACE.	Delay in clearance.
459931	Crew changed altitude to get out of clear air turbulence without Tokyo clearance because of the delay using CPDLC.	CPDLC delay.

Lessons learned:

1.) The urgency of the diversion can be lost when using CPDLC.
2.) Pilot to enter a maximum delay time the crew can wait for an ATC response for weather deviation.
3.) Voice communication used when CPDLC is not immediately effective.
4.) CPDLC technology should not contribute to an emergency.

E-3: Procedure Problem

ACN	DESCRIPTION	ISSUE
831471	B777 captain discovers that SLOP may not be an internationally accepted procedure when WSJC questions 1 mile offset on a M767 airway.	New procedures, training required.
695178	ACFT #1 WAS ISSUED DSCNT AND RERTE VIA CPDLC. TFC PICTURE CHANGED AND ACFT #1 WAS TOLD TO MAINTAIN FL360 AND ISSUED PREVIOUS ROUTING VIA AIDC. ACFT #1 STILL DSNDED INTO ACFT #2.	ACFT#1 did not understand or receive revised clearance.
664783	CPDLC TEST WITH MAASTRICHT/AMSTERDAM CTL IS CUMBERSOME AND UNSAFE.	Crew believes the workload for CPDLC is excessive.
616856	Deviation clearances are cause of confusion for crew.	See "Lessons learned #4" below this table.
556754	Pilot comments on use of data link during taxi procedures and does not feel it is safe.	Too much 'heads down' time
550342	DUE TO DIFFICULTIES WITH ATTEMPTING TO OBTAIN OCEANIC CLRNC FROM SHANWICK VIA DATA LINK, WE DID NOT RECEIVE OCEANIC CLRNC UNTIL 12 MINS PRIOR TO OCEANIC ENTRY POINT.	Delay getting clearance with CPDLC.
441715	Crew received CPDLC clearance: "*CLB TO FL370 AND MAINTAIN.*" Crew rejected clearance. Crew requested block FL350-FL370. ATC asked when can crew be at FL370. Crew sent back time. Crew received and accepted clearance: "CROSS 'SANTA' FIX AT AND MAINTAIN FL370, RPT REACHING". Crew forgot about clearance and remained at FL360.	Extended dialog about altitude requirements. Should the default CPDLC page be the message/history log?
429792	BECAME CONFUSED OVER THE DESIGNATORS OF ZAK AND ZOA AND WHAT EACH REPRESENTS.	Written terminology is different than spoken.
303614	Crew received CPDLC msg: "OAKS ATC CLRS ACR X DSND TO AND MAINTAIN FL310 RPT REACHING. DSCNT NECESSARY DUE TO OPPOSITE DIRECTION COMPANY TFC." When this message was displayed, two prompts were provided: ACCEPT or REJECT. The crew felt they had an option to accept this clearance or reject it. The crew rejected the clearance and maintained FL330, which caused confusion with ATC and a traffic conflict.	Lack of dialog using CPDLC and delay in sending and receiving can be problematic

Lessons learned:

1.) New procedures are bound to cause problems.
2.) Testing data link in a taxiing environment increases the pilot workload, which is generally not accepted by pilots. Pre-taxi assigned route is good but tends to change due to many factors. This change causes problems.
3.) Inherent delay in receiving Data Link reply.
4.) Comments from ACN:616856 crew about 'complex' requests:

AT XA40Z, WE RECEIVED A CLRNC FROM NADI CTL TO DEVIATE R OFF COURSE 50 NM. AT XA20Z, WE RECEIVED A CLRNC TO DEVIATE L 50 NM, BOTH DUE TO WX. WE ULTIMATELY DEVIATED R 30 NM. AFTER BEING CHANGED TO AUCKLAND CTL, THE NADI CTLR INQUIRED IF WE WERE

DEVIATING AND WHAT DIRECTION. WE INFORMED HIM R OFF COURSE 30 NM AND THAT WE WERE BACK ON COURSE AT THAT TIME. THE NATURE OF THE INQUIRY CAUSED CONCERN ON THE FLT CREW'S PART THAT WE HAD POSSIBLY RPTED BACK ON COURSE PRIOR TO INITIATING THE DEV. AN INVENTORY OF THE CPDLC ATC LOG INDICATED WE HAD NOT CANCELLED THE DEV REQUEST.

THIS INCIDENT BRINGS UP CERTAIN CONCERNS OF CPDLC DEV CLRNCS.
1) UNLIKE BLOCK ALT CLRNCS WHERE WE CAN INPUT FLXXX/FLYYY, L AND R DEV REQUESTS CANNOT BE CONVENIENTLY ENTERED IN ONE MESSAGE. WE EITHER HAVE TO SUBMIT TWO MESSAGES, ONE FOR L AND ONE FOR R, OR INPUT ONE DIRECTION AND ADD TEXT FOR THE OTHER. I FIND THE LATTER LACKING AS MOST OF THE TIME THE CTLR DOESN'T READ THE TEXT OR UNDERSTAND THE REQUEST AND JUST CLRS THE DEV TO THE MAIN DIRECTION AND NOT THE ONE REQUESTED IN THE TEXT.

2) WHEN TWO REQUESTS ARE SENT CONSECUTIVELY, DOES THE CTLR POSSIBLY THINK THE SECOND CANCELS OR OVERRIDES THE FIRST? THIS MIGHT BE THE CASE IN THE CURRENT SIT.

3) AS AN ASIDE, WHEN A REQUEST IS MADE FOR A DEV, THE CLRNC INCLUDES A REQUEST TO ‘RPT BACK ON RTE.’ THIS AUTOMATICALLY PUTS A 'BACK ON RTE' PROMPT IN THE ATC FMC PAGE. IF WE ASK FOR DEVS EACH WAY IN TWO SEPARATE MESSAGES, THERE ARE TWO OF THESE PROMPTS. IS EACH PROMPT SPECIFICALLY RELATED TO THE MESSAGE, ONE FOR L AND ONE FOR R? CAN WE DELETE ONE AND SEND THE OTHER AND THEN CANCEL BOTH DEV CLRNCS, OR DO WE NEED TO SEND BOTH?

E-4: Equipment Problem

ACN	DESCRIPTION	ISSUE
841810	A pilot reported that the flight attendants’ use of the cabin ACARS during international operations interfered with CPDLC/ADS communications with ATC.	
796356	The crew programmed the FMC to reestablish a 1-NM SLOP offset. This reprogramming caused the aircraft get 10 NM off course. Crew was not sure why this happened.	
521590	CREW IS UNABLE TO ESTABLISH CONTACT WITH OCEANIC CTLR VIA CPDLC.	

E-5: ATC Uplink Problems

ACN	DESCRIPTION	ISSUE
850779	Crew received an unsolicited CPDLC clearance message from Seattle Center as follows: *"Cleared Route Clearance Arrival: GOLDN5 Via Direct N4716.0W13151.0, Direct FULMR, Direct HEMLO, Direct ENI."* It was in an "FMC Uploadable" format, so the crew transferred the clearance to the FMC. The result was a track deviation when the FMC failed to fly direct between two waypoints as expected.	Crew failed to check the flight plan when it was entered in the FMS.
819758	Crew on a transpacific flight under **CPDLC** procedures found out at the end of the flight they had been out of **CPDLC** contact (*'ATC COMM TERMINATED'* message) for some time with no indication of same.	Crew was out of contact with ATC and did not know it.
802084	Crew OUT OF CONTACT (no CPDLC or voice) WITH ATC AND DISPATCH FOR OVER AN HOUR ON THE POLAR 3 ROUTE.	Polar route out of contact.
795253	Crew UNABLE TO MAINTAIN CPDLC COM/LISTENING WATCH WITH ATC ENROUTE THROUGH MAGADAN AIRSPACE WHILE ON POLAR ROUTES.	Polar route out of contact.
787787	ACR REQUESTING ALT CHANGE VIA CPDLC INITIATED CLIMB BUT WAS THEN CALLED VIA SELCAL ADVISING CLRNC WAS FOR ANOTHER ACFT.	CPDLC message was for wrong aircraft.
775917	UNABLE TO CONTACT MAGADAN CTL PRIOR TO ENTERING THEIR AIRSPACE; AIRCREW REVERSES COURSE. MOMENTS LATER CONTACT ESTABLISHED AND CLRNC OBTAINED.	Crew could not contact the next sector. This crew reversed course until cleared into the next sector. Other crews may continue.
775378	ACR FLT CREW ENCOUNTERS LOSS OF REQUIRED COM LINK WITH COMPANY ON POLAR ROUTE.	Polar route out of contact.
714311	ZOA CTLR DESCRIBED FAILURE OF OCEANIC DATA LINK, I.E., ADS AND CPDLC ON TWO CONSECUTIVE DAYS, INDICATING THIS TYPE OF PROB IS ONGOING.	ATC outage problems.
703591	ZOA CTLR DESCRIBED A RECURRING PROB WITH CPDLC-ADS FAILURES.	
701244	ZOA CTLR EXPRESSED CONCERN REGARDING NEW CPDLC EQUIP AND PROBS ENCOUNTERED, I.E., ACFT NOT RESPONDING OR INACCURATE RESPONSES.	Known problems with new equipment.
673156	ZOA CTLR EXPRESSED CONCERN REGARDING THE NEW OCEANIC EQUIP AND CLRNC CONFIRMATION PROCS UTILIZED.	
622539	ZOA ARTCC OCEANIC SECTOR NEAR GUAM AND TYO HAD A SERIOUS CPDLC EQUIP OUTAGE THAT SERIOUSLY DISRUPTED ATC SVC.	
561886	ZMA CTLR CONCERNED WITH UNTIMELY HOST COMPUTER SHUTDOWN COORD TO INSTALL NEW DATA LINK MEMORY SOFTWARE.	Equipment problems.

ACN	DESCRIPTION	ISSUE
575255	CREW CONFERRED WITH AN SFO COMRDO CO IN ORDER TO CLARIFY THAT THE ZOA OCEANIC CPDLC (CTLR-PLT DATALINK COMS) INTERFACE HAD FAILED. No indication to the crew that communication with ATC was active.	Loss of comms unknown to crew.
476461	Shannon ATC was busy and could not clear crew before crossing boundary. Crew received DATA LINK INDICATED BUSY AND DISPLAYED A *'DO NOT TRY AGAIN.'* Crew contacted ATC on VHV and HF. ATC cleared only to a waypoint and crew thought it was for the entire flight plan.	If ATC is too busy, it doesn't matter if the crew is sending messages by CPDLC or voice.
513920	Crew received CPDLC message as a different flight number. Message was for opposite direction aircraft.	Verify who the message is for.
424272	Crew sent clearance for block alt 350/370. ATC called crew on HF to rescind climb due to no clearance.	Use both CPDLC and voice to ensure message is understood or corrected.
416285	Crew received CPDLC clearance, but it was for a different aircraft.	Verify who the message is for.
411132	CREW FLYING IN NTTT AIRSPACE SENDS THE WRONG FLT NUMBER IN CPDLC DATA LINK. NTTT FINDS TWO ACFT WITH THE SAME FLT NUMBER AND ELIMINATES ONE OF THE FLT PLANS FOR THE DUPLICATE FLT NUMBER.	No protection against wrong information in response.

Lessons learned:

1.) Use of CPDLC requires complex equipment, protocol, and seems more susceptible to problems than voice.
2.) Outages and ground equipment problems without the crew knowledge can cause major problems. Status of the ground signal and equipment should be continuously monitored by airborne equipment.
3.) Ground equipment or controllers may send messages to wrong aircraft. Too easy to read and acknowledge without checking.
4.) Crew should check the aircraft identification on the UM to ensure the message is sent to the right aircraft.

E-6: CPDLC Would Have Helped

NOTE: Comments from the flight crews about CPDLC and data link as it relates to incidents they have experienced.

ACN	CREW/CONTROLLER COMMENT	INCIDENT
698410	If some of the 16 aircraft on frequency (even one) were using CPDLC, it would have helped.	Altitude deviation. Frequency congestion.
693679	IN FUTURE YRS, A DATA LINK SYS COULD REDUCE THE POSSIBILITY OF THESE EVENTS.	Crew descends through altitude on approach.
544545	THE OBVIOUS CHOICE AT THIS POINT IS A DATA LINK SYS.	Stuck mic at DCA.
542345	Crew believes that DATA LINK will prevent these errors.	ARTCC RADAR CTLR ADVISED A320 CLB TO THEIR ALTITUDE THAT THEY HAD OVERSHOT THEIR ASSIGNED ALT.
535466	DATA LINK CLEARANCES REALLY HELP ELIMINATE CONFUSION WHEN IT'S USED.	A B767 CREW HAD DIFFICULTY UNDERSTANDING THEIR CLRNC AS GIVEN BY REYKJAVIK CTL.

ACN	CREW/CONTROLLER COMMENT	INCIDENT
516940	WHEN ARE WE GOING TO SOLVE THESE TYPES OF HUMAN COM PROBS WITH SOME SORT OF DATA LINK/WRITTEN COM?	A B737 CREW HAD SIMILAR CALL SIGN MIX-UP WITH COMPANY FLT IN ZDC CLASS A AIRSPACE.
486430	I BELIEVE THESE TYPES OF MISTAKES WILL CONTINUE UNTIL A SYS CONSISTING OF A DATA LINK BTWN THE CTLRS AND PLTS IS BROUGHT INTO SVC.	AN FK100 FLC OVERSHOOTS THEIR ASSIGNED ALT WHEN ANSWERING TO THE WRONG CALL SIGN 6 MI S OF STEED INTXN WITH N90, NY.
478694	ATC AND PLTS NEED DATA LINK NOW!	AN A320 FLC ACCEPTS A LOWER ALT CLRNC FOR ANOTHER FLT WITH A SIMILAR SOUNDING CALL SIGN, DSNDS TO OCCUPIED ALT, AND IS FURTHER CLRED LOWER TO AVOID OPPOSITE DIRECTION TFC 40 MI N OF SAV, GA.
476044	HOW TECHNOLOGY CAN SOLVE THE ISSUE OF DATA LINK XMISSION THROUGH INEXPENSIVE XMISSION, RECEPTION, AND DISPLAY UNITS FOR ALL ACFT WITHIN THE ATC SYS.	A C182 PVT PLT EXPERIENCES AN NMAC WITH PAX ON BOARD. HE IS SO DISTURBED BY THIS FACT (THAT OF MISSING THE C172 BY 200 FT) THAT HE EXPERIENCES OTHER MISADVENTURES DUE TO LOSS OF FOCUS NEAR XYZ ARPT.
442820	WOULDN'T IT BE NICE TO HAVE A DATA LINK BACKUP WITH ATC?	A B757 CREW MISUNDERSTANDS THE CLRNC BUT IS UNAWARE OF THAT FACT UNTIL N90 CTLR ISSUES A NEW CLRNC THAT IS HIGHER THAN THE PREVIOUSLY 'ISSUED' CLRNC.
410977	AN INDICATOR WOULD BE THE THICKNESS OF OUR FLT MANUAL SECTION DEVOTED TO FANS. IT TAKES MANY WORDS AND DIAGRAMS TO DESCRIBE FANS OP, ALL FUNNELED THROUGH THE CDU'S. THE FOLLOWING IS A BRIEF LIST OF FANS/CPDLC POSITIVES AND NEGATIVES: POSITIVES: ▪ CPDLC SIMPLIFIES OR ELIMINATES DIFFICULTIES OF **HF RADIO COM** FOR ROUTINE POS RPTING AND ATC REQUESTS. • ALLOWS FOR DISPLAYED OR PRINTED **'PROOFS'** OF CLRNCS. NEGATIVES: ▪ CONFUSION CAN EXIST BECAUSE OF PARALLEL COM METHODOLOGY, ATC AND COMMERCIAL RADIO/COMPANY, BOTH USING SAME DATA LINK SYS. ▪ ATC (OAK OCEANIC) DOES NOT ACKNOWLEDGE ROUTINE POS RPTS. (IF COMMERCIAL RADIO DATA LINK IS USED FOR POS RPTS, OPERATOR ACKNOWLEDGES IMMEDIATELY.) THIS LEADS	A B747-400 CAPT WRITES A LIST OF POSITIVE AND NEGATIVE ATTRIBUTES OF FANS.

ACN	CREW/CONTROLLER COMMENT	INCIDENT
	TO SOME INSECURITY REGARDING COM INTEGRITY WHEN USING CPDLC. ▪ CONCEPT COMPLEXITY! PERTAINING TO PRESENT FANS. I AM A LINE CHK AIRMAN. I DEMONSTRATE AND CHK PROFICIENCY OF THIS ASPECT OF NAV/COM TO NEW AND EXISTING AIRMEN. THIS IS A VERY COMPLICATED SYS WHEN PRESENTED TO AIRMEN WHO ARE NEW TO AIRPLANE/GLASS COCKPIT/INTL OP, OR ALL THE ABOVE. FOR INSTANCE: - CDU SCREEN PRESENTATIONS ARE **NOT INTUITIVE**. - CDU **MULTI-PAGE MESSAGE** MAY EXIST BUT CAN BE MISSED. - USE IS LIMITED TO CERTAIN ROUTES ... DOES NOT CORRESPOND TO OAK OCEANIC AIRSPACE BOUNDARIES.	
392254	THE INSTALLATION OF DATA LINK TO DISPLAY THE ALT SET IN ACFT AUTOPLT ON CTLR DATA BLOCK COULD ELIMINATE THIS AND MOST OTHER READBACK/HEARBACK ERRORS.	RPTED LOSS OF SEPARATION WHEN FO OF ACR DC9 TAKES CLRNC FOR OTHER ACFT WITH SIMILAR CALL SIGN AND THE READBACK WITH CALL SIGN IS MISSED BY THE CTLR.
370191	ELECTRONIC DATA LINK MESSAGES FOR CLB/DSCNT CLRNCS WOULD CERTAINLY HELP PREVENT THIS TYPE OF ERROR.	B737-300 ACFT. WHEN FLC READ BACK CLRNC, THEY HAD READ BACK CLRNC FOR A SIMILAR CALL SIGN. ATC DIDN'T CATCH THE CALL SIGN ERROR EITHER. AS ACFT WAS CLBING THROUGH THE EXPECTED ALT, THE CTLR INTERVENED AND FLC LEVELED ACFT.
368451	UNTIL WE HAVE DATA LINK OR SOME OTHER SYS IN PLACE, RADIO COMS ARE CRITICAL TO ENSURE SAFE ACFT SEPARATION.	A320 ACFT ON DSCNT AND APCH TO LAX, HVY TFC, FREQ CONGESTION, RESTR VISIBILITY, RESULTED IN RPTR ACFT RECEIVING TCASII RA, WHICH THEY FOLLOWED.
365823	USE OF DATA LINK/DIRECT LINE COMS IN FOREIGN AIRSPACE REDUCES CONCERNS FOR MISINTERP DUE TO LANGUAGE CONSTRAINTS. BOTH WOULD BE POSSIBLE BUT FOR GOVERNMENTAL RESTRAINT IN THE USE OF THESE AIDS.	FLC OF B747-400 UNABLE TO CLARIFY REASON FOR NOT ACCEPTING A CLB CLRNC WITH SPD RESTR DUE TO LANGUAGE BARRIER.
299658	WAITING FOR DATA LINK TO SOLVE THE PROB PROMISES TO LEAVE US IN A BIND FOR QUITE SOME TIME.	MISUNDERSTOOD CLRNC, CONGESTED FREQ. ACFT INITIATED CLRNC MEANT FOR ANOTHER ACFT.
249834	I BELIEVE THAT EVERY EFFORT SHOULD BE EXPENDED TO EXPEDITE THE IMPLEMENTATION OF VHF VOICE AND DATA LINK COMS VIA SATELLITE FOR CTL OF OCEANIC AIR TFC.	EMER AUTH USED ON OCEANIC FLT DUE ENG MALFUNCTION.
222283	THIS SCENARIO COULD HAVE HAD A TRAGIC	AN ACR LGT CREW WAS DSNDING

ACN	CREW/CONTROLLER COMMENT	INCIDENT
	CONCLUSION. ALSO, ANOTHER GOOD REASON TO ACCELERATE DEVELOPMENT OF DATA LINK COM.	TO 10,000 FT AT 17 MI. THE CLRNC WAS 17.000 FT AT 10 MI.
190171	BUT WE NEED DATA LINK TO UNLOAD AND FREE UP THE RADIO FREQS FOR THE NON ROUTINE, AND ENSURE POSITIVE XMISSION AND RECEIPT OF CLRNCS.	UNABLE TO COM WITH CENTER CTLR FLT RECEIVED LATE DSCNT CLRNC. UNABLE TO MAKE XING RESTRICTION.
186663	DATA LINK WILL SOMEDAY HELP.	ACR MLG WRONG RWY APCH AT ATL.
175819	WE NEED DATA LINK CLRNCS TOO.	ACR MLG CAPT BECAME CONFUSED ABOUT AN AMENDED CLRNC THAT TOOK THE ACFT ACROSS THE ORIGINAL FILED TRACK.
172008	PERHAPS THE NEW CONCEPT OF DATA LINK TO CONVEY CLRNCS WITH PICTORIAL PRESENTATION OF THE CLRNC OR EVEN A HARD COPY WILL ELIMINATE CLRNC MISUNDERSTANDINGS AND ELIMINATE A VERY REAL AND PRESENT HAZARD TO FLYING.	FLC OF MLG ON DESCENT AND APCH TO DTW HAD CONFLICT WITH SAME COMPANY ACFT DEPARTING AND CLIMBING OUT OF DTW.
170517	I CONSIDER THE PROC FOR DATA LINK CLRNC DELIVERY TO BE UNSAFE BECAUSE OF INADEQUATE PROVISIONS FOR REVISION.	FLT CREW FOLLOWED DEP CLRNC THAT HAD BEEN DELIVERED TO THEM VIA DATA LINK—2 HOURS LATE. IN THE INTERIM DEP HAD GONE TO NIGHT NOISE ABATEMENT DEPS.
162601	THE WORKLOAD AT TIMES EXCEEDS THE CTLRS ABILITY, PARTICULARLY ON SOME HIGH-DENSITY ARR RTES. ALL CLRNCS MUST BE ACKNOWLEDGED. IF THERE IS DOUBT, REPEAT CLRNC INSTRUCTIONS. CONTINUE RESEARCH ON DATA LINK CLRNCS THAT ARE PRINTED OUT OR READ ON SCREENS IN ACFT. THIS WOULD LOWER THE NEED FOR RADIO XMISSIONS AND THE PROBS ASSOCIATED WITH THEM.	MISSED AMENDED CLRNC TO MAINTAIN FL220.
140202	THE BEST SOLUTION TO THE MISUNDERSTANDING IS A DATA-LINK TRANSFER.	FLT CREW OF WDB DEPARTING JFK UNDERSTOOD THAT THEY WERE CLEARED TO 15,000 FT, BUT PASSING THROUGH 11,300 FT; THE CTLR INFORMED THEM THAT THEY WERE SUPPOSEDLY TOLD TO MAINTAIN 11,000 FT.
94447	DATA LINK COULD NOT ONLY ELIMINATE THIS SOURCE OF ERROR BUT WOULD DECONGEST CTL FREQS GREATLY.	MIX-UP IN DESCENT CLRNC CAUSED ACFT TO DESCEND THROUGH ALT EXPECTED BY RECEIVING CENTER CTLR. OPERATIONAL DEVIATION.

NOTE: The comments from the flight crews about CPDLC and Data Link at it relates to incidents they have experienced

Appendix F – SC-214 Uplink Message Set

F-1: Data Fields Contained in SC-214 Message Set

The following legends describe the fields of information in the message set table (Table F-1) and the colors that identify them.

Column **Label**		**UM Table Column Description**
UM		The Uplink Message ID number: UM: Uplink Message – UM020 – CLIMB TO [level] ACL: ATC Clearance – UM ACL3 – AT [timesec] DESCENT VIA [procedure name] DT: D-TAXI – UM DT09 – TAXI [taxi route] 4D: 4-D Trajectory – UM 4D01 – IN THE CLIMB [speed schedule]
Message Element		Uplink message viewed by the pilot
Message Use		Description of the Message Element
Attribute	URG	Urgency – D: Distress, U: Urgent, N: Normal, L: Low
	ALERT	ALERT – H: High, M: Medium, L: Low, N: No alerting required
	RESP	Response – WU: Wilco/Unable, AN: Affirm/Neg, R: Roger, Y: Yes, N: No
Classification	CATEGORY	The category describes the part of the flight the message is directed to, or if the message is part of the CPDLC Message Management. Route, Speed, Altitude, Surface, Comms, Emergency, and Ack.
	TYPE	The Type describes how the pilot uses the message. Clearance, Expect, INFO, Report.
	Intent	How the ATC controller intends to use the UM: Inform, Now, On Condition, Confirm.
FMS Loadable	USE	**USE**: If the UM is or should be loadable. If the UM is already loaded, then where is it used (e.g., FANS). The grayed-out boxes indicate that the UM is not appropriate for FMS loadable.
	AIRCRAFT	**AIRCRAFT**: Current aircraft the message is loadable.
UM % (1)		The percentage of time ATC has transmitted the UM over a 10-year period in South Pacific oceanic routes.
Loadable %		The percentage of time ATC has transmitted a **loadable** UM over a 10-year period.

(1) The statistical data in the last two columns of the UM Table is obtained from the **ATC Data Link News** website at the following location: http://www.members.optusnet.com.au/~cjr/index.html [1].

ATC Data Link News seeks to provide operational information on the use of FANS-1/A data link communications technology available in current-generation commercial jet aircraft and modern Air Traffic Control facilities. Message Use statistics provide information on the most used FANS-1/A uplink message elements provided by participating South Pacific FANS Air Navigation Service Providers.

F-1.1Categories and Types of SC Messages

CATEGORY The category describes the part of the flight the message is directed to, or if the message is part of the CPDLC Message Management.	
Route	Route is the lateral navigation.
Speed	Speed is airspeed, true airspeed, ground speed, etc.
Altitude	Altitude is vertical control.
Surface	Surface is ground operations for taxi out or taxi out.
Comms	Comms is the communication management messages for CPDLC operations and information.
Emergency	Emergency messages.
Ack	ACK is an acknowledgment message to the pilot.

TYPE The Type describes how the pilot uses the message.	
Clearance	Clearance is a message that requires the pilot to navigate/guide the aircraft or communicate information to ATC.
Expect	Expect is a message that will alert the pilot of an impending clearance.
INFO	INFO is an information message that the pilot requests or ATC offers that does not require a response from the pilot.
Report	Report is a message that is required from the pilot.
Request	Pilot is requesting a clearance from ATC.

F-1.2- Message Attribute

For a given message, Urgency, Alert, Response, and Recall attributes shall be assigned for each message element. For a message containing multiple message elements, the message element with the highest precedence shall be assigned for each attribute for that message, as determined.

RESP – Response Attribute

Type	Response Required	Valid Responses Description
WU	Yes	DM0 WILCO DM1 UNABLE DM2 STANDBY
AN	Yes	DM4 AFFIRM DM5 NEGATIVE DM2 STANDBY
R	Yes	DM3 ROGER DM1 UNABLE DM2 STANDBY
Y	Yes	DMxx Any CPDLC downlink message
N	No	

URG – Urgency Attribute

Type	Description	Precedence
D	Distress	1
U	Urgent	2
N	Normal	3
L	Low	4

If received messages are queued for display, messages with the highest Urgency type shall be placed at the beginning of the queue. Messages with the same Urgency type shall be queued in order of receipt.

ALRT – Alert Attribute

a. If a received message has an “A/D” Alert type, a unique aural alert and a visual indication of message presence shall be initiated.

b. If a received message has an “A” Alert type, an aural alert and a visual indication of message presence shall be initiated. For this alert type, the aural alert may be the same as other aural alerts but shall be distinct from the aural alert used for the “A/D” Alert type.

Type	Description	Precedence
H	High	1
M	Medium	2
L	Low	3
N	No alerting required	4

Table F-1. SC-214 CPDLC Uplink Message Set

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM0	UNABLE	Indicates that ATC cannot comply with the request.	N	M	N	ACK	INFO	Respond	No	No	1.502	
UM001	STANDBY	Indicates that ATC has received the message and will respond.	N	L	N	ACK	INFO	Respond	No	No	3.588	
UM002	REQUEST DEFERRED	Indicates that ATC has received the request but it has been deferred until later.	N	L	N	ACK	INFO	Respond	No	No	0.269	
UM003	ROGER	Indicates that ATC has received and understood the message.	N	L	N	ACK	INFO	Respond	No	No	0.121	
UM004	AFFIRM	Yes.	N	L	N	ACK	INFO	Respond	No	No	0.026	
UM005	NEGATIVE	No.	N	L	N	ACK	INFO	Respond	No	No	0.019	
UM006	EXPECT [*level*]	Notification that a level change instruction should be expected.	L	L	R	Altitude	Expect	Inform	No	No	0.006	
UM008	EXPECT CLIMB AT [*position*]	Notification that an instruction should be expected for the aircraft to commence climb at the specified position.	L	L	R	Altitude	Expect	Inform	No	No	0.034	
UM010	EXPECT DESCENT AT [*position*]	Notification that an instruction should be expected for the aircraft to commence descent at the specified position.	L	L	R	Altitude	Expect	Inform	No	No	0.000	
UM012	EXPECT CRUISE CLIMB AT [*position*]	Notification that an instruction should be expected for the aircraft to commence cruise climb at the specified position.	L	L	R	Altitude	Expect	Inform	No	No	0.000	
UM245 (New 7)	EXPECT CLIMB AT [*timesec*]	Notification that an instruction should be expected for the aircraft to commence climb at the specified time.	L	L	R	Altitude	Expect	Inform	No	No	0.098	
UM246 (New 9)	EXPECT DESCENT AT [*timesec*]	Notification that an instruction should be expected for the aircraft to commence descent at the specified time.	L	L	R	Altitude	Expect	Inform	No	No	0.003	
UM247 (New 11)	EXPECT CRUISE CLIMB AT [*timesec*]	Notification that an instruction should be expected for the aircraft to commence cruise climb at the specified time.	L	L	R	Altitude	Expect	Inform	No	No	0.000	
UM296 (New UM ACL8)	EXPECT HIGHER AT [*timesec*]	Notification that a climb instruction may be issued at the specified time.	L	L	R	Altitude	Expect	Inform	No	No	-	

UM	Message Element	Use Description	Attribute URG	Attribute ALRT	Attribute RESP	Classification Category	Classification TYPE	Classification Intent	FMS Loadable USE	FMS Loadable AIRCRAFT	UM %	Load-able %
UM297 (New UM ACL9)	EXPECT HIGHER AT [*position*]	Notification that a climb instruction may be issued at the specified position.	L	L	R	**Altitude**	**Expect**	Inform	No	No	-	
UM298 (New UM ACL10)	EXPECT LOWER AT [*timesec*]	Notification that a descend instruction may be issued at the specified time.	L	L	R	**Altitude**	**Expect**	Inform	No	No	-	
UM299 (New UM ACL11)	EXPECT LOWER AT [*position*]	Notification that a descend instruction may be issued at the specified position.	L	L	R	**Altitude**	**Expect**	Inform	No	No	-	
UM300 (New UM ACL12)	AT [*timesec*] EXPECT [*level*]	Notification that at the specified time an instruction may be issued to reach the specified level.	L	L	R	**Altitude**	**Expect**	Inform	No	No	-	
UM301 (New UM ACL13)	AT [*position*] EXPECT [*level*]	Notification that at the specified position an instruction may be issued to reach the specified level.	L	L	R	**Altitude**	**Expect**	Inform	No	No	-	
UM302 (New UM ACL14)	EXPECT [*level*] [*timeduration*] AFTER DEPARTURE	Notification that at the specified amount of time after departure an instruction may be issued to reach the specified level.	L	L	R	**Altitude**	**Expect**	Inform	No	No	-	
UM19	MAINTAIN [level]	Instruction to maintain the specified level	N	M	WU	**Altitude**	**Clearance**	**Now**			0.619	2.976
UM020	CLIMB TO [*level*]	Instruction that a climb to a specified level is to commence and, once reached, the specified level is to be maintained.	N	M	WU	**Altitude**	**Clearance**	**Now**			9.798	49.857
UM022	AT [*position*] CLIMB TO [*level*]	Instruction that at the specified position a climb to the specified level is to commence and, once reached, the specified level is to be maintained.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.072	0.371
UM023	DESCEND TO [*level*]	Instruction that a descent to a specified level is to commence and, once reached, the specified level is to be maintained.	N	M	WU	**Altitude**	**Clearance**	**Now**			0.340	1.728
UM025	AT [*position*] DESCEND TO [*level*]	Instruction that at the specified position a descent to the specified level is to commence and, once reached, the specified level is to be maintained.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.002	0.011

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM027	CLIMB TO REACH [*level*] BY [*position*]	Instruction that a climb is to commence at a rate such that the specified level is reached at or before the specified position.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.583	2.966
UM029	DESCEND TO REACH [*level*] BY [*position*]	Instruction that a descent is to commence at a rate such that the specified level is reached at or before the specified position.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.082	0.419
UM034	CRUISE CLIMB TO [*level*]	Instruction that a cruise climb is to commence and continue until the specified level is reached.	N	M	WU	**Altitude**	**Clearance**	**Now**			0.016	0.082
UM035	WHEN ABOVE [*level*] COMMENCE CRUISE CLIMB	Instruction that a cruise climb can commence once above the specified level.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.000	0.000
UM036	EXPEDITE CLIMB TO [*level*]	Instruction that the climb to the specified level should be made at the aircraft's best rate.	U	M	WU	**Altitude**	**Clearance**	**Now**			0.000	0.001
UM037	EXPEDITE DESCENT TO [*level*]	Instruction that the descent to the specified level should be made at the aircraft's best rate.	U	M	WU	**Altitude**	**Clearance**	**Now**			0.000	0.000
UM038	IMMEDIATELY CLIMB TO [*level*]	Urgent instruction to immediately climb to the specified level.	D	H	WU	**Altitude**	**Clearance**	**Now**			0.000	0.001
UM039	IMMEDIATELY DESCEND TO [*level*]	Urgent instruction to immediately descend to the specified level.	D	H	WU	**Altitude**	**Clearance**	**Now**			0.000	0.000
UM046	CROSS [*position*] AT [*level*]	Instruction that the specified position is to be crossed at the specified level. This may require the aircraft to modify its climb or descent profile.	N	M	WU	**Altitude**	**Clearance**	**On Condition**	**FANS**	**748 757 767 777 787**	**0.004**	**0.018**
UM047	CROSS [*position*] AT OR ABOVE [*level*]	Instruction that the specified position is to be crossed at or above the specified level.	N	M	WU	**Altitude**	**Clearance**	**On Condition**	**FANS**	**748 757 767 777 787**	0.000	0.001
UM048	CROSS [*position*] AT OR BELOW [*level*]	Instruction that the specified position is to be crossed at or below the specified level.	N	M	WU	**Altitude**	**Clearance**	**On Condition**	**FANS**	**748 757 767 777 787**	0.000	0.000
UM049	CROSS [*position*] AT AND MAINTAIN [*level*]	Instruction that the specified position is to be crossed at the specified level and that level is to be maintained when reached.	N	M	WU	**Altitude**	**Clearance**	**On Condition**	yes	**748 787**	0.001	0.005

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM050	CROSS [*position*] BETWEEN [*level*] AND [*level*]	Instruction that the specified position is to be crossed at a level between the specified levels.	N	M	WU	**Altitude**	**Clearance**	**On Condition**	yes	**748 787**	0.000	0.000
UM055	CROSS [*position*] AT [*speed*]	Instruction that the specified position is to be crossed at the specified speed and the specified speed is to be maintained until further advised.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.000	0.003
UM056	CROSS [*position*] AT OR LESS THAN [*speed*]	Instruction that the specified position is to be crossed at a speed equal to or less than the specified speed and the specified speed or less is to be maintained until further advised.	N	M	WU	**Altitude**	**Clearance**	**On Condition**	yes	**787**	0.000	0.001
UM057	CROSS [*position*] AT OR GREATER THAN [*speed*]	Instruction that the specified position is to be crossed at a speed equal to or greater than the specified speed and the specified speed or greater is to be maintained until further advised.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.000	0.000
UM061	CROSS [*position*] AT AND MAINTAIN [*level*] AT [*speed*]	Instruction that the specified position is to be crossed at the specified level and speed and the level and speed are to be maintained.	N	M	WU	**Altitude**	**Clearance**	**On Condition**			0.000	0.000
UM171	CLIMB AT [*vertical rate*] MINIMUM	Instruction to climb at not less than the specified rate.	N	M	WU	**Altitude**	**Clearance**	Clearance Info			0.000	0.000
UM172	CLIMB AT [*vertical rate*] MAXIMUM	Instruction to climb at not more than the specified rate.	N	M	WU	**Altitude**	**Clearance**	Clearance Info			0.000	0.000
UM173	DESCEND AT [*vertical rate*] MINIMUM	Instruction to descend at not less than the specified rate.	N	M	WU	**Altitude**	**Clearance**	Clearance Info			0.000	0.000
UM174	DESCEND AT [*vertical rate*] MAXIMUM	Instruction to descend at not more than the specified rate.	N	M	WU	**Altitude**	**Clearance**	Clearance Info			0.000	0.000
UM209	REACH [*level*] BY [*position*]	Instruction that a change of level is to continue, but at a rate such that the specified level is reached at or before the specified position.	N	M	WU	**Altitude**	**Clearance**	**Now**			-	-
UM219	STOP CLIMB AT [*level*]	Instruction to stop the climb below the previously assigned level.	U	M	WU	**Altitude**	**Clearance**	**Now**			-	-
UM220	STOP DESCENT AT [*level*]	Instruction to stop the descent above the previously assigned level.	U	M	WU	**Altitude**	**Clearance**	**Now**			-	-

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM248 (New 21)	AT [*timesec*] CLIMB TO [*level*]	Instruction that at the specified time a climb to the specified level is to commence and, once reached, the specified level is to be maintained.	N	M	WU	Altitude	Clearance	On Condition			0.042	0.212
UM249 (New24)	AT [*timesec*] DESCEND TO [*level*]	Instruction that at a specified time a descent to a specified level is to commence and, once reached, the specified level is to be maintained.	N	M	WU	Altitude	Clearance	On Condition			0.009	0.048
UM250 (New 26)	CLIMB TO REACH [*level*] BY [*timsece*]	Instruction that a climb is to commence at a rate such that the specified level is reached at or before the specified time.	N	M	WU	Altitude	Clearance	On Condition			0.524	2.668
UM251 (New 28)	DESCEND TO REACH [*level*] BY [*timsece*]	Instruction that a descent is to commence at a rate such that the specified level is reached at or before the specified time.	N	M	WU	Altitude	Clearance	On Condition			0.048	0.244
UM281 (New 192)	REACH [*level*] BY [*timesec*]	Instruction that a change of level is to continue, but at a rate such that the specified level is reached at or before the specified time.	N	M	WU	Altitude	Clearance	On Condition			-	-
UM290 (New UM ACL2)	DESCEND VIA [*procedure name*]	Instruction to descend via the specified procedure.	N	M	WU	Altitude	Clearance	On Condition			-	-
UM291 (New UM ACL3)	AT [*timesec*] DESCEND VIA [*procedure name*]	Instruction that at the specified time to descend via the specified procedure.	N	M	WU	Altitude	Clearance	On Condition			-	-
UM292 (New UM ACL4)	AT [*position*] DESCEND VIA [*procedure name*]	Instruction that when reaching the specified position to descend via the specified procedure.	N	M	WU	Altitude	Clearance	On Condition			-	-
UM293 (New UM ACL5)	CLIMB VIA [*procedure name*]	Instruction to climb via the specified procedure.	N	M	WU	Altitude	Clearance	Now			-	-
UM294 (New UM ACL6)	AT [*timesec*] CLIMB VIA [*procedure name*]	Instruction that at the specified time to climb via the specified procedure.	N	M	WU	Altitude	Clearance	On Condition			-	-
UM295 (New UM ACL7)	AT [*position*] CLIMB VIA [*procedure name*]	Instruction that when reaching the specified position to climb via the specified procedure.	N	M	WU	Altitude	Clearance	On Condition			-	-

UM	Message Element	Use Description	Attribute URG	Attribute ALRT	Attribute RESP	Classification Category	Classification TYPE	Classification Intent	FMS Loadable USE	FMS Loadable AIRCRAFT	UM %	Load-able %
UM149	CAN YOU ACCEPT [*level*] AT [*position*]	Instruction to report whether or not the specified level can be accepted at the specified position.	N	L	AN	Altitude	Report	Negotiate	No	No	0.047	
UM200	REPORT MAINTAINING	Instruction used in conjunction with a level clearance to report maintaining the level assigned.	N	M	WU	Altitude	Report	Confirm	No	No	-	
UM231	STATE PREFERRED LEVEL	Instruction to indicate the pilot's preferred level.	L	L	Y	Altitude	Report	Negotiate	No	No	-	
UM232	STATE TOP OF DESCENT	Instruction to indicate the pilot's preferred time and/or position to commence descent to the aerodrome of intended arrival.	L	L	Y	Altitude	Report	Confirm	No	No	-	
UM277 (New 150)	CAN YOU ACCEPT [*level*] AT [*timesec*]	Instruction to report whether or not the specified level can be accepted at the specified time.	N	L	AN	Altitude	Report	Negotiate	No	No	0.044	
UM101	AT [*position*] EXPECT [*speed*]	Notification that a speed instruction may be issued to be effective at the specified position.	L	L	R	Speed	Expect	Inform	No	No	0.001	
UM102	AT [*level*] EXPECT [*speed*]	Notification that a speed instruction may be issued to be effective at the specified level.	L	L	R	Speed	Expect	Inform	No	No	0.000	
UM104	AT [*position*] EXPECT [*speed*] TO [*speed*]	Notification that a speed range instruction may be issued to be effective at the specified position.	L	L	R	Speed	Expect	Inform	No	No	0.000	
UM105	AT [*level*] EXPECT [*speed*] TO [*speed*]	Notification that a speed range instruction may be issued to be effective at the specified level.	L	L	R	Speed	Expect	Inform	No	No	0.000	
UM273 (New 100)	AT [*timesec*] EXPECT [*speed*]	Notification that a speed instruction may be issued to be effective at the specified time.	L	L	R	Speed	Expect	Inform	No	No	0.000	
UM274 (New 103)	AT [*timesec*] EXPECT [*speed*] TO [*speed*]	Notification that a speed range instruction may be issued to be effective at the specified time.	L	L	R	Speed	Expect	Inform	No	No	0.000	
UM106	MAINTAIN [speed]	Instruction that the specified speed is to be maintained.	N	M	WU	Speed	Clearance	Now			0.105	0.536
UM107	MAINTAIN PRESENT SPEED	Instruction that the present speed is to be maintained.	N	M	WU	Speed	Clearance	Now			0.000	0.003
UM108	MAINTAIN [*speed*] OR GREATER	Instruction that the specified speed or a higher speed is to be maintained.	N	M	WU	Speed	Clearance	Now			0.129	0.657

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM109	MAINTAIN [*speed*] OR LESS	Instruction that the specified speed or a lower speed is to be maintained.	N	M	WU	Speed	Clearance	Now			0.118	0.602
UM110	MAINTAIN [*speed*] TO [*speed*]	Instruction that a speed within the specified range is to be maintained.	N	M	WU	Speed	Clearance	Now			0.001	0.003
UM111	INCREASE SPEED TO [*speed*]	Instruction that the present speed is to be increased to the specified speed and maintained until further advised.	N	M	WU	Speed	Clearance	Now			0.001	0.007
UM112	INCREASE SPEED TO [*speed*] OR GREATER	Instruction that the present speed is to be increased to the specified speed or higher and maintained at or above the specified speed until further advised.	N	M	WU	Speed	Clearance	Now			0.000	0.001
UM113	REDUCE SPEED TO [*speed*]	Instruction that the present speed is to be reduced to the specified speed and maintained until further advised.	N	M	WU	Speed	Clearance	Now			0.003	0.015
UM114	REDUCE SPEED TO [*speed*] OR LESS	Instruction that the present speed is to be reduced to the specified speed or less and maintained at or below the specified speed until further advised.	N	M	WU	Speed	Clearance	Now			0.000	0.002
UM115	DO NOT EXCEED [*speed*]	Instruction that the specified speed is not to be exceeded.	N	M	WU	Speed	Clearance	Now			0.000	0.001
UM116	RESUME NORMAL SPEED	Notification that the aircraft need no longer comply with the previously issued speed restriction.	N	M	WU	Speed	Clearance	Now			0.366	1.862
UM188	AFTER PASSING [*position*] MAINTAIN [*speed*]	Instruction that after passing the specified position the specified speed is to be maintained.	N	M	WU	Speed	Clearance	On Condition			-	-
UM189	ADJUST SPEED TO [*speed*]	Instruction that the present speed is to be changed to the specified speed.	N	M	WU	Speed	Clearance	Now			-	-
UM222	NO SPEED RESTRICTION	Notification that the aircraft may keep its preferred speed without restriction.	L	L	R	Speed	Clearance	Now			-	-
UM223	REDUCE TO MINIMUM APPROACH SPEED	Instruction to reduce present speed to the minimum safe approach speed.	N	M	WU	Speed	Clearance	Now			-	-
UM308 (New UM ACL20)	MAINTAIN MAXIMUM FORWARD SPEED	Instruction to maintain the maximum forward speed.	N	M	WU	Speed	Clearance	Now			-	-

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM309 (New UM ACL21)	MAINTAIN SLOWEST PRACTICAL SPEED	Instruction to maintain the slowest practical speed.	N	M	WU	Speed	Clearance	Now			-	-
UM310 (New UM ACL22)	AT [*level*] MAINTAIN [*speed*]	Instruction to maintain the specified speed upon reaching the specified level.	N	M	WU	Speed	Clearance	On Condition			-	-
UM334 (New UM 4D01)	IN THE CLIMB [*speed schedule*]	Instruction for the pilot to fly the specified mach and/or IAS during the climb.	N	M	WU	Speed	Clearance	On Condition			-	-
UM335 (New UM 4D02)	IN THE DESCENT [*speed schedule*]	Instruction for the pilot to fly the specified mach and/or IAS during the descent, above 10,000 feet.	N	M	WU	Speed	Clearance	On Condition			-	-
UM151	WHEN CAN YOU ACCEPT [*speed*]	Instruction to report the earliest time when the specified speed can be accepted.	N	L	Y	Speed	Report	Negotiate	No	No	0.002	
UM087	EXPECT DIRECT TO [*position*]	Notification that a clearance may be issued to fly directly to the specified position.	L	L	R	Route	Expect	Inform	No	No	0.000	
UM088	AT [*position*] EXPECT DIRECT TO [*position*]	Notification that a clearance may be issued to fly directly from the first specified position to the next specified position.	L	L	R	Route	Expect	Inform	No	No	0.001	
UM090	AT [*level*] EXPECT DIRECT TO [*position*]	Notification that a clearance may be issued to fly directly to the specified position, commencing when the specified level is reached.	L	L	R	Route	Expect	Inform	No	No	0.000	
UM070	EXPECT BACK ON ROUTE BY [*position*]	Notification that a clearance may be issued to enable the aircraft to rejoin the cleared route at or before the specified position.	L	L	R	Route	Expect	Inform	No	No	0.000	
UM099	EXPECT [*procedure name*]	Notification that a clearance may be issued for the aircraft to fly the specified procedure.	L	L	R	Route	Expect	Inform	No	No	0.000	
UM224	NO DELAY EXPECTED	ATS advisory that no delay is expected.	N	L	R	Route	Expect	Inform	No	No	-	
UM225	DELAY NOT DETERMINED	ATS advisory that the expected delay has not been determined.	N	L	R	Route	Expect	Inform	No	No	-	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM263 (New 71)	EXPECT BACK ON ROUTE BY [*timesec*]	Notification that a clearance may be issued to enable the aircraft to rejoin the cleared route at or before the specified time.	L	L	R	**Route**	**Expect**	Inform	No	No	0.000	
UM269 (New 85)	EXPECT [*route clearance enhanced*]	Notification that a clearance may be issued to fly on the specified route.	L	L	R	**Route**	**Expect**	Inform	No	No	0.000	
UM270 (New 86)	AT [*position*] EXPECT [*route clearance enhanced*]	Notification that a clearance may be issued to fly on the specified route from the specified position.	L	L	R	**Route**	**Expect**	Inform	No	No	0.000	
UM271 (New 89)	AT [*timesec*] EXPECT DIRECT TO [*position*]	Notification that a clearance may be issued to fly directly to the specified position, commencing at the specified time.	L	L	R	**Route**	**Expect**	Inform	No	No	0.000	
UM272 (New 93)	EXPECT FURTHER CLEARANCE AT [*timesec*]	Notification that an onwards clearance may be issued at the specified time.	L	L	R	**Route**	**Expect**	Inform	No	No	0.000	
UM284 (New 226)	EXPECTED APPROACH TIME [*timesec*]	ATS advisory that the aircraft may expect to be cleared to commence its approach procedure at the specified time.	N	L	R	**Route**	**Expect**	Inform	No	No	-	
UM064	OFFSET [*specified distance*] [*direction*] OF ROUTE	Instruction to fly a parallel track to the cleared route at a displacement of the specified distance in the specified direction.	N	M	WU	**Route**	**Clearance**	**Now**	**FANS**	**737 747 757 767 787**	0.010	0.050
UM065	AT [*position*] OFFSET [*specified distance*] [*direction*] OF ROUTE	Instruction to fly a parallel track to the cleared route at a displacement of the specified distance in the specified direction and commencing at the specified position.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.003	0.014
UM067	PROCEED BACK ON ROUTE	Instruction that the cleared flight route is to be rejoined.	N	M	WU	**Route**	**Clearance**	**Now**	yes	**748 787**	0.001	0.006
UM068	REJOIN ROUTE BY [*position*]	Instruction that the cleared flight route is to be rejoined at or before the specified position.	N	M	WU	**Route**	**Clearance**	**On Condition**			0.028	0.141

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM072	RESUME OWN NAVIGATION	Instruction to resume own navigation following a period of tracking or heading clearances. May be used in conjunction with an instruction on how or where to rejoin the cleared route.	N	M	WU	**Route**	**Clearance**	Now	No		0.000	
UM074	PROCEED DIRECT TO [*position*]	Instruction to proceed directly from the present position to the specified position.	N	M	WU	**Route**	**Clearance**	**Now**	**FANS**	**737 747 757 767 787**	**0.688**	**3.503**
UM075	WHEN ABLE PROCEED DIRECT TO [*position*]	Instruction to proceed, when able, directly to the specified position.	N	M	WU	**Route**	**Clearance**	**On Condition**	**FANS**	**748 757 767 787**	**0.430**	**2.188**
UM077	AT [*position*] PROCEED DIRECT TO [*position*]	Instruction to proceed, at the specified position, directly to the next specified position.	N	M	WU	**Route**	**Clearance**	**On Condition**	**FANS**	**737 747 757 767 777 787**	**0.377**	**1.925**
UM078	AT [*level*] PROCEED DIRECT TO [*position*]	Instruction to proceed, upon reaching the specified level, directly to the specified position.	N	M	WU	**Route**	**Clearance**	**On Condition**			0.000	0.002
UM081	CLEARED [*procedure name*]	Instruction to proceed in accordance with the specified procedure.	N	M	WU	**Route**	**Clearance**	**Now**	**FANS**	**737 747 757 767 777 787**	0.003	0.014
UM082	CLEARED TO DEVIATE UP TO [*specified distance*] [*direction*] OF ROUTE	Approval to deviate up to the specified distance from the cleared route in the specified direction.	N	M	WU	**Route**	**Clearance**	**Now**	No		5.462	
UM084	AT [*position*] CLEARED [*procedure name*]	Instruction to proceed from the specified position via the specified procedure.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.000	0.001
UM091	HOLD AT [*position*] MAINTAIN [*level*] INBOUND TRACK [*degrees*] [*direction*] TURNS [*leg type*]	Instruction to enter a holding pattern with the specified characteristics at the specified position and level.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.000	0.002

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM092	HOLD AT *[position]* AS PUBLISHED MAINTAIN *[level]*	Instruction to enter a holding pattern with the published characteristics at the specified position and level.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.000	0.000
UM094	TURN *[direction]* HEADING *[degrees]*	Instruction to turn left or right as specified on to the specified heading.	N	M	WU	**Route**	**Clearance**	**Now**			0.000	0.002
UM095	TURN *[direction]* GROUND TRACK *[degrees]*	Instruction to turn left or right as specified on to the specified track.	N	M	WU	**Route**	**Clearance**	**Now**			0.000	0.000
UM096	CONTINUE PRESENT HEADING	Instruction to continue to fly on the current heading.	N	M	WU	**Route**	**Clearance**	**Now**			0.000	0.001
UM097	AT *[position]* FLY HEADING *[degrees]*	Instruction to fly on the specified heading from the specified position.	N	M	WU	**Route**	**Clearance**	On Condition			0.000	0.001
UM098	IMMEDIATELY TURN *[direction]* HEADING *[degrees]*	Instruction to turn immediately left or right as specified onto the specified heading.	D	H	WU	**Route**	**Clearance**	**Now**			0.000	0.000
UM176	MAINTAIN OWN SEPARATION AND VMC	Notification that the pilot is responsible for maintaining separation from other traffic and is also responsible for maintaining visual meteorological conditions.	N	M	WU	**Route**	**Clearance**	**Now**			0.000	0.000
UM190	FLY HEADING *[degrees]*	Instruction to fly on the specified heading.	N	M	WU	**Route**	**Clearance**	**Now**			-	-
UM215	TURN *[direction]* *[degrees]* DEGREES	Instruction to turn a specified number of degrees left or right.	N	M	WU	**Route**	**Clearance**	**Now**			-	-
UM221	STOP TURN HEADING *[degrees]*	Instruction to stop turn at the specified heading prior to reaching the previously assigned heading.	U	M	WU	**Route**	**Clearance**	**Now**			-	-
UM236	LEAVE CONTROLLED AIRSPACE	Instruction to leave controlled airspace.	N	M	WU	**Route**	**Clearance**	**Now**			-	-
UM252 (New 51)	CROSS *[position]* AT *[RTAtimesec]*	Instruction that the specified position is to be crossed at the specified time.	N	M	WU	**Route**	**Clearance**	**On Condition**	**FANS**	**737 747 757 777 787 A30**	**0.067**	**0.341**

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM253 (New 52)	CROSS [*position*] AT OR BEFORE [*RTAtimesec*]	Instruction that the specified position is to be crossed at or before the specified time.	N	M	WU	**Route**	**Clearance**	**On Condition**	**FANS**	**737 747 757 777 787 A30**	**0.033**	**0.170**
UM254 (New 53)	CROSS [*position*] AT OR AFTER [*RTAtimesec*]	Instruction that the specified position is to be crossed at or after the specified time.	N	M	WU	**Route**	**Clearance**	**On Condition**	**FANS**	**737 747 757 777 787 A30**	**0.041**	**0.209**
UM255 (New 54)	CROSS [*position*] BETWEEN [*RTAtimesec*] AND [*RTAtimesec*]	Instruction that the specified position is to be crossed at a time between the specified times.	N	M	WU	**Route**	**Clearance**	**On Condition**			0.000	0.000
UM256 (New 58)	CROSS [*position*] AT [*RTAtimesec*] AT [*level*]	Instruction that the specified position is to be crossed at the specified time and the specified level.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.000	0.000
UM257 (New 59)	CROSS [*position*] AT OR BEFORE [*RTAtimesec*] AT [*level*]	Instruction that the specified position is to be crossed at or before the specified time and at the specified level.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.000	0.000
UM258 (New 60)	CROSS [*position*] AT OR AFTER [*RTAtimsec*] AT [*level*]	Instruction that the specified position is to be crossed at or after the specified time and at the specified level.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787 A35 A38**	0.000	0.000
UM259 (New 62)	CROSS [*position*] AT [*RTAtimesec*] AT AND MAINTAIN [*level*]	Instruction that at the specified time the specified position is to be crossed at the specified level and the level is to be maintained.	N	M	WU	**Route**	**Clearance**	**On Condition**	yes	**748 787**	0.001	0.004
UM260 (New 63)	CROSS [*position*] AT [*RTAtimesec*] AT AND MAINTAIN [*level*] AT [*speed*]	Instruction that at the specified time the specified position is to be crossed at the specified level and speed and the level and speed are to be maintained.	N	M	WU	**Route**	**Clearance**	**On Condition**			0.000	0.000
UM261 (New 66)	AT [*timesec*] OFFSET [*specified distance*] [*direction*] OF ROUTE	Instruction to fly a parallel track to the cleared route at a displacement of the specified distance in the specified direction and commencing at the specified time.	N	M	WU	**Route**	**Clearance**	**On Condition**			0.000	0.000
UM262 (New 69)	REJOIN ROUTE BY [*timesec*]	Instruction that the cleared flight route is to be rejoined at or before the specified time.	N	M	WU	**Route**	**Clearance**	**Now**			0.003	0.014

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM264 (New 73)	[*departure clearance enhanced*]	Notification to the aircraft of the instructions to be followed from departure until the specified clearance limit.	N	M	WU	**Route**	**Clearance**	**Now**	**FANS**	**737 747 757 767 787**	0.004	0.020
UM265 (New 76)	AT [*timesec*] PROCEED DIRECT TO [*position*]	Instruction to proceed, at the specified time, directly to the specified position.	N	M	WU	**Route**	**Clearance**	**On Condition**			0.012	0.062
UM266 (New 79)	CLEARED TO [*position*] VIA [*route clearance enhanced*]	Instruction to proceed to the specified position via the specified route.	N	M	WU	**Route**	**Clearance**	**Now**	**FANS**	**737 747 757 767 787 A30**	**0.097**	**0.496**
UM267 (New 80)	CLEARED [*route clearance enhanced*]	Instruction to proceed via the specified route.	N	M	WU	**Route**	**Clearance**	**Now**	**FANS**	**737 747 757 767 787 A30**	**0.090**	**0.458**
UM268 (New 83)	AT [*position*] CLEARED [*route clearance enhanced*]	Instruction to proceed from the specified position via the specified route.	N	M	WU	**Route**	**Clearance**	**On Condition**	**FANS**	**737 747 757 767 787 A30**	**0.051**	**0.258**
UM289 (New UM ACL2)	REST OF ROUTE UNCHANGED	Indication that after the indicated modification the route is unchanged.	N	L	N	**Route**	**Clearance**	**Now**			-	-
UM303 (New UM ACL15)	CLEARED TO DEVIATE UP TO [*degrees*] DEGREES [*direction*] OF ROUTE	Instruction to deviate up to the specified degrees and direction of the route	N	M	WU	**Route**	**Clearance**	**Now**			-	-
UM304 (New UM ACL16)	CLEARED TO [*position*]	Instruction to proceed directly to the specified position.	N	M	WU	**Route**	**Clearance**	**Now**			-	-
UM305 (New UM ACL17)	HOLD [*direction*] AS PUBLISHED	Instruction to hold the specified direction.	N	M	WU	**Route**	**Clearance**	**On Condition**			-	-
UM306 (New UM ACL18)	HOLD [*direction*] ON [*inbound radial*] RADIAL / [*airway*] [*direction*] TURNS [*leg type*] LEGS.	Instruction to enter a holding pattern with the specified characteristics at the specified direction.	N	M	WU	**Route**	**Clearance**	**On Condition**			-	-

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM336 (New UM 4D03)	CANCEL [*position*] TIME CONSTRAINT	Instruction that a time constraint previously issued for the specified position has been cancelled.	N	M	WU	Route	Clearance	Now			-	-
UM337 (New UM 4D04)	[*clearance name*] CLEARANCE LIMIT [*position*]	Instruction that a time constraint has been issued for the specified position.	N	M	WU	Route	Clearance	Now			-	-
UM338 (New UM 4D05)	MAINTAIN TIME CONSTRAINT	Instruction that a previously issued time constraint remains in effect for the specified position.	N	M	WU	Route	Clearance	Now			-	-
UM339 (New UM 4D06)	AT [*position*] CLEARED TO [*position*] VIA [*route clearance enhanced*]	Instruction to proceed from the first specified position to the second specified position via the specified route	N	M	WU	Route	Clearance	On Condition			-	-
UM130	REPORT PASSING [*position*]	Instruction to report when the aircraft has passed the specified position.	N	L	WU	Route	Report	On Condition	No	No	0.001	
UM132	REPORT POSITION	Instruction to report the present position.	N	M	Y	Route	Report	Now	No	No	0.002	
UM133	REPORT PRESENT LEVEL	Instruction to report the present level.	N	M	Y	Route	Report	Now	No	No	0.003	
UM134	REPORT [*speed type*] [*speed type*] [*speed type*] SPEED	Instruction to report the requested speed.	N	M	Y	Route	Report	Now	No	No	0.449	
UM135	CONFIRM ASSIGNED LEVEL	Instruction to confirm and acknowledge the currently assigned level.	N	L	Y	Route	Report	Now	No	No	0.055	
UM136	CONFIRM ASSIGNED SPEED	Instruction to confirm and acknowledge the currently assigned speed.	N	L	Y	Route	Report	Now	No	No	0.002	
UM137	CONFIRM ASSIGNED ROUTE	Instruction to confirm and acknowledge the currently assigned route.	N	L	Y	Route	Report	Now	No	No	0.048	
UM138	CONFIRM TIME OVER REPORTED WAYPOINT	Instruction to confirm the previously reported time over the last reported waypoint.	N	L	Y	Route	Report	Now	No	No	0.000	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM139	CONFIRM REPORTED WAYPOINT	Instruction to confirm the identity of the previously reported waypoint.	N	L	Y	Route	Report	Now	No	No	0.000	
UM140	CONFIRM NEXT WAYPOINT	Instruction to confirm the identity of the next waypoint.	N	L	Y	Route	Report	Now	No	No	0.002	
UM141	CONFIRM NEXT WAYPOINT ETA	Instruction to confirm the previously reported estimated time at the next waypoint.	N	L	Y	Route	Report	Now	No	No	0.129	
UM142	CONFIRM ENSUING WAYPOINT	Instruction to confirm the identity of the next but one waypoint.	N	L	Y	Route	Report	Now	No	No	0.001	
UM143	CONFIRM REQUEST	The request was not understood. It should be clarified and resubmitted.	N	L	Y	Route	Report	Now	No	No	0.001	
UM144	CONFIRM SQUAWK	Instruction to report the selected (SSR) code.	N	L	Y	Route	Report	Now	No	No	0.001	
UM145	REPORT HEADING	Instruction to report the present heading.	N	M	Y	Route	Report	Now	No	No	0.000	
UM146	REPORT GROUND TRACK	Instruction to report the present ground track.	N	M	Y	Route	Report	Now	No	No	0.000	
UM147	REQUEST POSITION REPORT	Instruction to make a position report.	N	M	Y	Route	Report	Now	No	No	10.789	
UM152	WHEN CAN YOU ACCEPT [*specified distance*] [*direction*] OFFSET	Instruction to report the earliest time when the specified offset track can be accepted.	N	L	Y	Route	Report	Negotiate	No	No	0.000	
UM181	REPORT DISTANCE [*to/from*] [*position*]	Instruction to report the present distance to or from the specified position.	N	M	Y	Route	Report	Now	No	No	0.057	
UM217	REPORT ARRIVAL	Instruction to report that the aircraft has landed.	N	M	WU	Route	Report	Now	No	No	-	
UM228	REPORT ETA [*position*]	Instruction to report the estimated time of arrival at the specified position.	L	L	Y	Route	Report	Now	No	No	-	
UM229	REPORT ALTERNATE AERODROME	Instruction to report the preferred alternate aerodrome for landing.	L	L	Y	Route	Report	Now	No	No	-	

UM	Message Element	Use Description	Attribute URG	Attribute ALRT	Attribute RESP	Classification Category	Classification TYPE	Classification Intent	FMS Loadable USE	FMS Loadable AIRCRAFT	UM %	Load-able %
UM243	REPORT CLEAR OF WEATHER	Instruction to report when the aircraft is clear of adverse meteorological conditions and a clearance to regain cleared flight route can be accepted.	N	L	WU	Route	Report	Now	No	No	-	
UM280 (New 184)	AT [*timesec*] REPORT DISTANCE [*to/from*] [*position*]	Instruction to report at the specified time the distance to or from the specified position.	N	L	Y	Route	Report	On Condition	No	No	-	
UM314 (New UM DT04)	EXPECT [*clearance type*] [*assigned time*]	Notification that a specified taxi clearance may be issued at the time required to meet the specified time.	L	L	R	Surface	Expect	Inform	No	No	-	
UM315 (New UM DT05)	EXPECT TAXI [*taxi route*]	Notification that a taxi clearance may be issued on the specified taxi route.	L	L	R	Surface	Expect	Inform	No	No	-	
UM311 (New UM ACL01)	START UP APPROVED [*assigned time*]	Instruction that engine start-up is approved at the specified time.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM312 (New)	CANCEL START UP	Instruction to cancel engine start-up.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM313 (New UM DT03)	PUSH BACK APPROVED [*pushback information*] [*assigned time*]	Instruction that push back is approved at the specified location in the specified direction commencing at the specified time.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM317 (New UM DT07)	REMAIN [*preposition direction location*]	Instruction to remain in the specified direction of specified location.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM318 (New UM DT08)	CROSS [*position information*]	Instruction to cross the specified location.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM319 (New UM DT09)	TAXI [*taxi route*]	Instruction to taxi to the specified location without a hold short instruction.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM320 (New UM DT10)	RUNWAY [*runway*] TAXI [*taxi route*]	Instruction to taxi to the specified location with a hold short position.	N	M	WU	Surface	Clearance	Now	No	No	-	
UM321 (New UM DT11)	WHEN REACHING [*position information*]	Instruction that the subsequent action can commence when the specified position is reached.	N	M	WU	Surface	Clearance	On Condition	No	No	-	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM322 (New UM DT12)	HOLD POSITION	Instruction to hold the current position.	U	H	WU	Surface	Clearance	Now	No	No	-	
UM323 (New UM DT 13)	FOR REMOTE DE-ICING	The associated instruction is issued in order to perform remote de-icing.	L	L	N	Surface	Clearance	Now	No	No	-	
UM325 (New UM DT15)	REVISED	The associated instruction is a revision to a previously issued instruction.	U	H	N	Surface	Clearance	Now	No	No	-	
UM327 (New UM DT17)	ENGINE SHUTDOWN PERMITTED	Indicates that the flight crew is permitted to shut down engines.	N	M	N	Surface	Clearance	Now	No	No	-	
UM329 (New UM DT19)	INTERSECTION DEPARTURE [*intersection*]	Indicates the intersection departure for a taxi clearance or taxi route information.	N	N	N	Surface	Clearance	Now	No	No	-	
UM330 (New UM DT20)	[*graphic taxi route*]	Indicates a graphical depiction of the taxi clearance.	N	N	N	Surface	Clearance	Now	No	No	-	
UM331 (New UM DT21)	[*position information*] [*assigned time*] CONTACT [*facility function ground*] [*frequency*]	Instruction that at the specified position/time the ground facility with the specified name is to be contacted on the specified frequency.	N	M	WU	Surface	Clearance	On Condition	No	No	-	
UM332 (New UM DT22)	STANDARD	For use when local standard procedures are applicable.	N	L	N	Surface	Clearance	Now	No	No	-	
UM333 (New UM DT23)	HOLD SHORT [*position information*]	Instruction that the aircraft is to hold short of the specified position.	N	H	WU	Surface	Clearance	On Condition	No	No	-	
UM316 (New UM DT06)	WHEN CAN YOU ACCEPT [*clearance type*]	Request for the earliest time at which the specified clearance can be accepted.	N	L	Y	Surface	Report	Negotiate	No	No	-	
UM324 (New UM DT14)	CAN YOU ACCEPT INTERSECTION [*position information*] FOR RUNWAY [*runway*]	Instruction to report whether or not the specified intersection can be accepted on the specified runway.	N	M	AN	Surface	Report	Negotiate	No	No	-	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM326 (New UM DT16)	DEPARTURES STOPPED	Indicates that departures have been stopped and flights are not being released.	N	M	N	Surface	INFO	Inform	No	No	-	
UM328 (New UM DT18)	[*distance ground*] AVAILABLE	Indicates the remaining length of the runway for an intersection departure.	N	N	N	Surface	INFO	Inform	No	No	-	
UM131	REPORT REMAINING FUEL AND PERSONS ON BOARD	Instruction to report the amount of fuel remaining and the number of persons on board.	U	M	Y	Emergency	Report	Emergenc y	No	No	0.000	
UM235	ROGER 7500	Notification of receipt of unlawful interference message.	U	H	N	Emergency	INFO	Inform	No	No	-	
UM117	CONTACT [*unit name*] [*frequency*]	Instruction that the ATS unit with the specified ATS unit name is to be contacted on the specified frequency.	N	M	WU	Comms	Clearance	Now	No	No	12.134	
UM118	AT [*position*] CONTACT [*unit name*] [*frequency*]	Instruction that at the specified position the ATS unit with the specified ATS unit name is to be contacted on the specified frequency.	N	M	WU	Comms	Clearance	On Condition	No	No	14.173	
UM120	MONITOR [*unit name*] [*frequency*]	Instruction that the ATS unit with the specified ATS unit name is to be monitored on the specified frequency.	N	M	WU	Comms	Clearance	Now	No	No	1.249	
UM121	AT [*position*] MONITOR [*unit name*] [*frequency*]	Instruction that at the specified position the ATS unit with the specified ATS unit name is to be monitored on the specified frequency.	N	M	WU	Comms	Clearance	On Condition	No	No	5.882	
UM123	SQUAWK [*code*]	Instruction that the specified code (SSR code) is to be selected.	N	M	WU	Comms	Clearance	Now	No	No	7.102	
UM124	STOP SQUAWK	Instruction that the SSR transponder responses are to be disabled.	N	M	WU	Comms	Clearance	Now	No	No	0.000	
UM125	SQUAWK MODE CHARLIE	Instruction that the SSR transponder responses should include level information.	N	M	WU	Comms	Clearance	Now	No	No	0.000	
UM126	STOP SQUAWK MODE CHARLIE	Instruction that the SSR transponder responses should no longer include level information.	N	M	WU	Comms	Clearance	Now	No	No	0.000	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM237	REQUEST AGAIN WITH NEXT	Indicates that the request cannot be responded to by the current unit, and that it should be requested from the next unit	N	L	N	Comms	Clearance	On Condition	No	No	-	
UM238	SECONDARY FREQUENCY [*frequency*]	Notification that the secondary frequency is as specified.	N	L	R	Comms	Clearance	Now	No	No	-	
UM239	STOP ADS-B TRANSMISSION	Notification that the ADS-B transmissions are to be level information.	N	M	WU	Comms	Clearance	Now	No	No	-	
UM240	TRANSMIT ADS-B ALTITUDE	Instruction that the ADS B transmissions should include level information.	N	M	WU	Comms	Clearance	Now	No	No	-	
UM241	STOP ADS-B ALTITUDE TRANSMISSION	Instruction that the ADS-B transmissions should no longer include level information.	N	M	WU	Comms	Clearance	Now	No	No	-	
UM242	TRANSMIT ADS-B IDENT	Instruction that the 'ident' function of the ADS-B emitter is too be activated.	N	M	WU	Comms	Clearance	Now	No	No	-	
UM275 (New 119)	AT [*timesec*] CONTACT [*unit name*] [*frequency*]	Instruction that at the specified time the ATS unit with the specified ATS unit name is to be contacted on the specified frequency.	N	M	WU	Comms	Clearance	On Condition	No	No	0.555	
UM276 (New 122)	AT [*timesec*] MONITOR [*unit name*] [*frequency*]	Instruction that at the specified time the ATS unit with the specified ATS unit name is to be monitored on the specified frequency.	N	M	WU	Comms	Clearance	On Condition	No	No	0.018	
UM179	SQUAWK IDENT	Instruction that the 'ident' function on the SSR transponder is to be actuated.	N	M	WU	Comms	Report	Now	No	No	0.001	
UM182	CONFIRM ATIS CODE	Instruction to report the identification code of the last ATIS received.	N	L	Y	Comms	Report	Now	No	No	0.000	
UM288 (New UM ACM4)	VERIFY MONITORED FREQUENCY [*frequency*]	Instruction to verify the currently monitored frequency.	N	N	WU	Comms	Report	Now	No	No	-	
UM307 (New UM ACL19)	REPORT REQUIRED RVR	Request to provide the required runway visual range.	N	M	Y	Comms	Report	Now	No	No	-	
UM154	RADAR SERVICE TERMINATED	ATS advisory that the radar service is terminated.	N	L	R	Comms	INFO	Inform	No	No	0.552	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM155	RADAR CONTACT [*position*]	ATS advisory that radar contact has been established at the specified position.	N	M	R	Comms	INFO	Inform	No	No	0.010	
UM156	RADAR CONTACT LOST	ATS advisory that radar contact has been lost.	N	M	R	Comms	INFO	Inform	No	No	0.087	
UM158	ATIS [*atis code*]	ATS advisory that the ATIS information identified by the specified code is the current ATIS information.	N	L	R	Comms	INFO	Inform	No	No	0.004	
UM159	ERROR [*error information*]	A system generated message notifying that the ground system has detected an error.	U	M	N	Comms	INFO	SMM	No	No	-	
UM160	NEXT DATA AUTHORITY [*facility*]	Notification to the avionics that the specified data authority is the next data authority. If no data authority is specified, this indicates that any previously specified next data authority is no longer valid.	L	N	N	Comms	INFO	SMM	No	No	-	
UM162	MESSAGE NOT SUPPORTED BY THIS ATS UNIT	Notification that the ground system does not support this message.	L	L	N	Comms	INFO	SMM	No	No	-	
UM168	DISREGARD	The indicated communication should be ignored.	U	M	R	Comms	INFO	Now	No	No	0.032	
UM191	ALL ATS TERMINATED	ATS advisory that the aircraft is entering airspace in which no air traffic services are provided and all existing air traffic services are terminated.	N	M	R	Comms	INFO	Inform	No	No	-	
UM193	IDENTIFICATION LOST	Notification that radar identification has been lost.	N	M	R	Comms	INFO	Inform	No	No	-	
UM210	IDENTIFIED [*position*]	ATS advisory that the aircraft has been identified on radar at the specified position.	N	M	R	Comms	INFO	Inform	No	No	-	
UM211	REQUEST FORWARDED	Indicates that the ATC has received the request and has passed it to the next control authority.	N	L	N	Comms	INFO	Inform	No	No	-	
UM212	[*facility designation*] ATIS [*atis code*] CURRENT	ATS advisory that the specified ATIS information at the specified airport is current.	N	L	R	Comms	INFO	Inform	No	No	-	
UM218	REQUEST ALREADY RECEIVED	Indicates to the pilot that the request has already been received on the ground.	L	N	N	Comms	INFO	Inform	No	No	-	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM227	LOGICAL ACKNOWLEDGMENT	Confirmation to the aircraft system that the ground system has received the message to which the logical acknowledgment refers and found it acceptable for display to the responsible person.	N	M	N	Comms	INFO	SMM	No	No	-	
UM233	USE OF LOGICAL ACKNOWLEDG-MENT PROHIBITED	Notification to the pilot that messages sent requiring a logical acknowledgment will not be accepted by this ground system.	N	M	N	Comms	INFO	SMM	No	No	-	
UM234	FLIGHT PLAN NOT HELD	Notification that the ground system does not have a flight plan for that aircraft.	L	L	N	Comms	INFO	SMM	No	No	-	
UM244	IDENTIFICATION TERMINATED	ATS advisory that the radar and/or ADS-B is terminated.	N	L	R	Comms	INFO	Inform	No	No	-	
UM278 (New 153)	ALTIMETER [*altimeter*] [*timesec*]	ATS advisory that the altimeter setting should be the specified setting.	N	L	R	Comms	INFO	Inform	No	No	0.001	
UM279 (New 157)	CHECK STUCK MICROPHONE [*frequency value*]	Instruction that a continuous transmission is detected on the specified frequency. Check the microphone button.	U	M	N	Comms	INFO	Inform	No	No	0.009	
UM282 (New 213)	[*facility designation*] ALTIMETER [*altimeter*] [*timesec*]	ATS advisory that the specified altimeter setting relates to the specified facility.	N	L	R	Comms	INFO	Inform	No	No	-	
UM283 (New 214)	RVR RUNWAY [*runway rvr enhanced*]	ATS advisory that indicates the RVR value(s) for the specified runway.	N	M	R	Comms	INFO	Inform	No	No	-	
UM285 (New UM ACM1)	CURRENT ATC UNIT [*unitName*]	Indication of the name of the current ATC unit.	N	N	N	Comms	INFO	Inform	No	No	-	
UM286 (New UM ACM2)	CPDLC IN USE	Indication that CPDLC is now being used, when previously it was indicated that CPDLC was not in use.	N	L	N	Comms	INFO	Inform	No	No	-	
UM287 (New UM ACM3)	CPDLC NOT IN USE	Indication that CPDLC will not be used until so notified.	N	L	N	Comms	INFO	Inform	No	No	-	

UM	Message Element	Use Description	Attribute			Classification			FMS Loadable		UM %	Load-able %
			URG	ALRT	RESP	Category	TYPE	Intent	USE	AIRCRAFT		
UM340	LATENCY TIME VALUE [*latency value*]	Provides the maximum one-way uplink message transmission delay.	N	L	N	Comms	INFO	SMM	No	No	-	
UM164	WHEN READY	The associated instruction may be complied with at any future time.	L	N	N	Comms	Msg Mod	NA	No	No	0.764	
UM165	THEN	Used to link two messages, indicating the proper order of execution of clearances/ instructions.	L	N	N	Comms	Msg Mod	NA	No	No	0.000	
UM166	DUE TO [*traffic type*] TRAFFIC	The associated instruction is issued due to traffic considerations.	L	N	N	Comms	Msg Mod	NA	No	No	1.132	
UM167	DUE TO AIRSPACE RESTRICTION	The associated instruction is issued due to airspace restrictions.	L	N	N	Comms	Msg Mod	NA	No	No	0.085	
UM177	AT PILOT'S DISCRETION	Used in conjunction with a clearance/ instruction to indicate that the pilot may execute when prepared to do so.	L	L	N	Comms	Msg Mod	NA	No	No	-	
UM230	IMMEDIATELY	The associated instruction is to be complied with immediately.	D	H	N	Comms	Msg Mod	NA	No	No	-	

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Appendix G – Loadable Uplink Messages

The list of currently loadable UMs for the Honeywell avionics are:

- 777 loadable UMs:
  - 46, 47, 48, 51, 52, 53, 64, 73, 74, 75, 77, 79, 80, 81, 83
- 787 loadable UMs:
  - 46, 47, 48, 49, 50, 51, 52, 53, 56, 58, 59, 60, 62, 64, 65, 67, 73, 74, 75, 77, 79, 80, 81, 83, 84, 91, 92

UM	MESSAGE	B747-400 FMS LOADABLE UPLINK MESSAGE RULES
46	CROSS [*position*] AT [*level*]	If the [position] is a fix in the active route, the FMS loads the specified [altitude] in a manner consistent with an AT altitude constraint on the RTE LEGS page.
47	CROSS [*position*] AT OR ABOVE [*level*]	If the [position] is a fix in the active route, the FMS loads the specified [altitude] in a manner consistent with an AT OR ABOVE altitude constraint on the RTE LEGS page. (*Not loadable on the 747-400.*)
48	CROSS [*position*] AT OR BELOW [*level*]	If the [position] is a fix in the active route, the FMS loads the specified [altitude] in a manner consistent with an AT OR BELOW altitude constraint on the RTE LEGS page. (*Not loadable on the 747-400.*)
51	CROSS [position] AT [RTAtimesec]	If the [position] is a fix in the active route, the FMS loads the specified [time] in a manner consistent with an RTA time entry on the RTA PROGRESS page.
52	CROSS [*position*] AT OR BEFORE [*RTAtimesec*]	If the [position] is a fix in the active route, the FMS loads the specified [time] in a manner consistent with an AT OR BEFORE RTA time entry on the RIA PROGRESS page.
53	CROSS [*position*] AT OR AFTER [*RTAtimesec*]	If the [position] is a fix in the active route, the FMS loads the specified [time] in a manner consistent with an AT OR BEFORE RTA time entry on the RIA PROGRESS page.
64	OFFSET [specified distance] [direction] OF ROUTE	If the [direction] is specified as left or right and the [distance offset] is specified in nautical miles and is less than or equal to 99 NM, the FMS loads the data in a manner consistent with an offset entry on the RTE page.
73	[departure clearance enhanced]	The FMS attempts to load the [route clearance] portion of the pre-departure clearance as defined below.
74	PROCEED DIRECT TO [*position*]	The FMS inserts the [position] as the first fix in the active route. If the [position] matches a fix already in the active route, the route between the current aircraft position and the matching fix IS collapsed. Otherwise, the inserted fix is followed by a discontinuity, followed by the remainder of the active route.
75	WHEN ABLE PROCEED DIRECT TO [*position*]	The FMS inserts the [position] as the first fix in the active route. If the [position] matches a fix already in the active route, the route between the current aircraft position and the matching fix IS collapsed. Otherwise, the inserted fix is followed by a discontinuity, followed by the remainder of the active route. (*Not loadable on the 747-400.*)
77	AT [*position*] PROCEED DIRECT TO [*position*]	If the first [position] is a fix in the active route, the FMS performs the following. If the second [position] exists in the active route, the route IS collapsed between the two fixes. Otherwise, the second [position] is inserted as a fix in the active route immediately after the first [position], followed by a discontinuity, followed by the remainder of the active route.
79	CLEARED TO [position] VIA [route clearance enhanced]	The FMS attempts to load the [routeclearance] portion of the clearance as defined below. If the [position] IS a fix in the active route, the FMS replaces all fixes upstream of that fix with the specified [routeclearance]. If the [position] is not a fix in the active route, the FMS inserts the [routeclearance] before the existing route, followed by a discontinuity, followed by the existing route.

UM	MESSAGE	B747-400 FMS LOADABLE UPLINK MESSAGE RULES
80	CLEARED [route clearance enhanced]	The FMS attempts to load the [routeclearance] as defined below.
81	CLEARED [procedure name]	The FMS loads the [procedurename] by selecting the matching procedure and transition (if specified) on the DEPARTURES or ARRIVALS page, as appropriate for the specified [proceduretype]. (*Not loadable on the 747-400.)*
82	CLEARED TO DEVIATE UP TO [*specified distance*] [*direction*] OF ROUTE	The FMS attempts to load the [routeclearance] portion of the clearance as defined below. If the [position] is a fix in the active route, the FMS replaces all fixes downstream of that fix with the specified [routeclearance]. If the [position] is not a fix in the active route, the FMS inserts the [position], then the [routeclearance], at the end of the existing route, preceded by a discontinuity.

Appendix H – Manufacturer Automation Philosophies

Source: CRM Developers Group, 1997 [http://www.crm-devel.org/resources/paper/autophil.htm] and the Federal Aviation Administration.

Airbus Philosophy on Automation

- ... Automation must not reduce overall aircraft reliability; it should enhance aircraft and systems safety, efficiency and economy.
- Automation must not lead the aircraft out of the safe flight envelope and it should maintain the aircraft within the normal flight envelope.
- Automation should allow the operator to use the safe flight envelope to its full extent, should this be necessary due to extraordinary circumstances.
- Within the normal flight envelope, the automation must not work against operator inputs, except when absolutely necessary for safety ...

Boeing Flight Deck Automation Philosophy

- The pilot is the final authority for the operation of the airplane.
- Both crew members are ultimately responsible for the safe conduct of the flight.
- Flight crew tasks, in order of priority, are: safety, passenger comfort, and efficiency.
- Design for crew operations based on pilot's past training and operational experience.
- Design systems to be error tolerant.
- The hierarchy of design alternatives is: simplicity, redundancy, and automation.
- Apply automation as a tool to aid, not replace, the pilot.
- Address fundamental human strengths, limitations, and individual differences – for both normal and non-normal operations.
- Use new technologies and functional capabilities only when:
  - They result in clear and distinct operational or efficiency advantages, and
  - There is no adverse effect to the human-machine interface.

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Appendix I – Analysis of SC 214 Messages Across Model Types

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
0	UNABLE	X				X		X	
1	STANDBY	X				X		X	
2	REQUEST DEFERRED	X				X			
3	ROGER	X				X		X	
4	AFFIRM	X				X		X	
5	NEGATIVE	X				X		X	
6	EXPECT [altitude]	X				X			
7	EXPECT CLIMB AT [time]	X				X			
8	EXPECT CLIMB AT [position]	X				X			
9	EXPECT DESCENT AT [time]	X				X			
10	EXPECT DESCENT AT [position]	X				X			
11	EXPECT CRUISE CLIMB AT [time]	X				X			
12	EXPECT CRUISE CLIMB AT [position]	X				X			
13	AT [time] EXPECT CLIMB TO [altitude]	X				X			
14	AT [position] EXPECT CLIMB TO [altitude]	X				X			
15	AT [time] EXPECT DESCENT TO [altitude]	X				X			
16	AT [position] EXPECT DESCENT TO [altitude]	X				X			
17	AT [time] EXPECT CRUISE CLIMB TO [altitude]	X				X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
18	AT [position] EXPECT CRUISE CLIMB TO [altitude]	X				X			
19	MAINTAIN [altitude]	X				X		X	
20	CLIMB TO AND MAINTAIN [altitude]	X		To MCP		X		X	
21	AT [time] CLIMB TO AND MAINTAIN [altitude]	X			T	X			
22	AT [position] CLIMB TO AND MAINTAIN [altitude]	X			T	X			
23	DESCEND TO AND MAINTAIN [altitude]	X		To MCP		X		X	
24	AT [time] DESCEND TO AND MAINTAIN [altitude]	X			T	X			
25	AT [position] DESCEND TO AND MAINTAIN [altitude]	X			T	X			
26	CLIMB TO REACH [altitude] BY [time]	X		To MCP		X		X	
27	CLIMB TO REACH [altitude] BY [position]	X		To MCP		X		X	
28	DESCEND TO REACH [altitude] BY [time]	X		To MCP		X		X	
29	DESCEND TO REACH [altitude] BY [position]	X		To MCP		X			
30	MAINTAIN BLOCK [altitude] TO [altitude]	X		To MCP		X			
31	CLIMB TO AND MAINTAIN BLOCK [altitude] TO [altitude]	X		To MCP		X			
32	DESCEND TO AND MAINTAIN BLOCK [altitude] TO [altitude]	X		To MCP		X			
33	CRUISE [altitude]	X		To MCP		X			
34	CRUISE CLIMB TO [altitude]	X		To MCP		X			
35	CRUISE CLIMB ABOVE [altitude]	X		To MCP		X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
36	EXPEDITE CLIMB TO [altitude]	X		To MCP		X			
37	EXPEDITE DESCENT TO [altitude]	X		To MCP		X			
38	IMMEDIATELY CLIMB TO [altitude]	X		To MCP		X			
39	IMMEDIATELY DESCEND TO [altitude]	X		To MCP		X			
40	IMMEDIATELY STOP CLIMB AT [altitude]	X		To MCP		X			
41	IMMEDIATELY STOP DESCENT AT [altitude]	X		To MCP		X			
42	EXPECT TO CROSS [position] AT [altitude]	X				X			
43	EXPECT TO CROSS [position] AT OR ABOVE [altitude]	X				X			
44	EXPECT TO CROSS [position] AT OR BELOW [altitude]	X				X			
45	EXPECT TO CROSS [position] AT AND MAINTAIN [altitude]	X				X			
46	CROSS [position] AT [altitude]	X	T			X	T	X	T
47	CROSS [position] AT OR ABOVE [altitude]	X	T			X	T	X	T
48	CROSS [position] AT OR BELOW [altitude]	X	T			X	T	X	T
49	CROSS [position] AT AND MAINTAIN [altitude]	X	T			X	T		
50	CROSS [position] BETWEEN [altitude] AND [altitude]	X	T			X	T		
51	CROSS [position] AT [time]	X	T			X	T	X	T
52	CROSS [position] AT OR BEFORE [time]	X	T			X	T	X	T
53	CROSS [position] AT OR AFTER [time]	X	T			X	T	X	T

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
54	CROSS [position] BETWEEN [time] AND [time]	X				X		X	
55	CROSS [position] AT [speed]	X				X		X	
56	CROSS [position] AT OR LESS THAN [speed]	X	T			X			
57	CROSS [position] AT OR GREATER THAN [speed]	X				X			
58	CROSS [position] AT [time] AT [altitude]	X	T			X	T		
59	CROSS [position] AT OR BEFORE [time] AT [altitude]	X	T			X	T		
60	CROSS [position] AT OR AFTER [time] AT [altitude]	X	T			X	T		
61	CROSS [position] AT AND MAINTAIN [altitude] AT [speed]	X				X		X	
62	AT [time] CROSS [position] AT AND MAINTAIN [altitude]	X	T			X	T		
63	AT [time] CROSS [position] AT AND MAINTAIN [altitude] AT [speed]	X				X			
64	OFFSET [direction][distanceoffset]	X	T			X	T	X	T
65	AT [position] OFFSET [direction][distanceoffset]	X	T			X	T		
66	AT [time] OFFSET [direction][distanceoffset]	X			T	X			
67	PROCEED BACK ON ROUTE	X	T			X			
68	REJOIN ROUTE BY [position]	X				X			
69	REJOIN ROUTE BY [time]	X				X			
70	EXPECT BACK ON ROUTE BY [position]	X				X			
71	EXPECT BACK ON ROUTE	X				X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
	BY [time]								
72	RESUME OWN NAVIGATION	X				X		X	
73	PREDEPARTURE CLEARANCE	X	T			X	T		
74	PROCEED DIRECT TO [position]	X	T			X	T	X	
75	WHEN ABLE PROCEED DIRECT TO	X	T			X	T		
76	AT [time] PROCEED DIRECT TO [position]	X			T	X			
77	AT [position] PROCEED DIRECT TO [position]	X	T			X	T		
78	AT [altitude] PROCEED DIRECT TO [position]	X			T	X			
79	CLEARED TO [position] VIA ROUTE CLEARANCE	X	T			X	T	X	T
80	CLEARED ROUTE CLEARANCE	X	T			X	T	X	T
81(a)	CLEARED [procedure]	X	T			X	T		
81(b)	CLEARED [procedure][proceduretransition]	X	T			X	T		
82	CLEARED TO DEVIATE UP TO [direction][distanceoffset]	X				X		X	
83	AT [position] CLEARED ROUTE CLEARANCE	X	T			X	T		
84(a)	AT [position] CLEARED [procedure]	X	T			X	T		
84(b)	AT [position] CLEARED [procedure][proceduretransition]	X	T			X	T		
85	EXPECT ROUTE CLEARANCE	X				X			
86	AT [position] EXPECT ROUTE CLEARANCE	X				X			
87	EXPECT DIRECT TO	X				X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
	[position]								
88	AT [position] EXPECT DIRECT TO [position]	X				X			
89	AT [time] EXPECT DIRECT TO [position]	X				X			
90	AT [altitude] EXPECT DIRECT TO [position]	X				X			
91(a)	HOLD AT [position] MAINTAIN	X	T			X	T		
	[altitude] INBOUND TRACK	X				X			
	[degrees]/[direction] TURN	X				X			
	LEG TIME [legType]	X				X			
OR		X				X			
91(b)	HOLD AT [position] MAINTAIN [altitude] INBOUND TRACK	X	T			X	T		
	[degrees]/[direction] TURN LEG DIST [legType]	X				X			
91(c)	HOLD AT [position] MAINTAIN [altitude] INBOUND TRACK	X	T			X	T		
	[degrees]/[direction] TURN	X				X			
92	HOLD AT [position] AS PUBLISHED MAINTAIN [altitude]	X	T			X	T	X	T
93	EXPECT FURTHER CLEARANCE AT [time]	X				X			
94	TURN [direction] HEADING [degrees]	X		To MCP		X		X	
95	TURN [direction] GROUND TRACK [degrees]	X		To MCP		X			
96	FLY PRESENT HEADING	X				X		X	

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
97	AT [position] FLY HEADING [degrees]	X			T	X			
98	IMMEDIATELY TURN [direction] HEADING [degrees]	X		To MCP		X			
99(a)	EXPECT [procedure]	X				X			
99(b)	EXPECT [procedure][proceduretransition]	X				X			
100	AT [time] EXPECT [speed]	X				X			
101	AT [position] EXPECT [speed]	X				X			
102	AT [altitude] EXPECT [speed]	X				X			
103	AT [time] EXPECT [speed] TO [speed]	X				X			
104	AT [position] EXPECT [speed] TO [speed]	X				X			
105	AT [altitude] EXPECT [speed] TO [speed]	X				X			
106	MAINTAIN [speed]	X		To MCP		X		X	
107	MAINTAIN PRESENT SPEED	X				X		X	
108	MAINTAIN [speed] OR GREATER	X		To MCP		X		X	
109	MAINTAIN [speed] OR LESS	X		To MCP		X		X	
110	MAINTAIN [speed] TO [speed]	X		To MCP		X			
111	INCREASE SPEED TO [speed]	X		To MCP		X			
112	INCREASE SPEED TO [speed] OR GREATER	X		To MCP		X			
113	REDUCE SPEED TO [speed]	X		To MCP		X			
114	REDUCE SPEED TO [speed] OR LESS	X		To MCP		X			
115	DO NOT EXCEED [speed]	X		To MCP		X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
116	RESUME NORMAL SPEED	X				X		X	
	CONTACT [icaofacilityname]	X				X			
117 a)	[icaofacilityfunction] ON	X		To RMP		X			
	[frequency]	X				X			
117 b)	CONTACT [icaofacilitydesignation]	X		To RMP		X		X	
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
118 a)	AT [position] CONTACT	X		To RMP	T	X			
	[icaofacilityname]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
118 b)	AT [position] CONTACT	X		To RMP	T	X			
	[icaofacilitydesignation]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
119 a)	AT [time] CONTACT [icaofacilityname]	X		To RMP	T	X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
119 b)	AT [time] CONTACT	X		To RMP	T	X			
	[icaofacilitydesignation]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
120 a)	MONITOR [icaofacilityname]	X		To RMP		X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
120 b)	MONITOR [icaofacilitydesignation]	X		To RMP		X		X	
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
121 a)	AT [position] MONITOR	X		To RMP	T	X			
	[icaofacilityname]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
121 b)	AT [position] MONITOR	X		To RMP	T	X			
	[icaofacilitydesignation]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
122 a)	AT [time] MONITOR	X		To RMP	T	X			
	[icaofacilityname]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
122 b)	AT [time] MONITOR	X		To RMP	T	X			
	[icaofacilitydesignation]	X				X			
	[icaofacilityfunction] ON	X				X			
	[frequency]	X				X			
123	SQUAWK [beaconCode]	X		To RMP		X		X	

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
124	STOP SQUAWK	X				X			
125	SQUAWK ALTITUDE	X				X			
126	STOP ALTITUDE SQUAWK	X				X			
127	REPORT BACK ON ROUTE	X				X			
128	REPORT LEAVING [altitude]	X				X			
129	REPORT LEVEL [altitude]	X				X			
130	REPORT PASSING [position]	X				X			
131	REPORT REMAINING FUEL AND SOULS ON BOARD	X				X			
132	CONFIRM POSITION	X				X			
133	CONFIRM ALTITUDE	X				X		X	
134	CONFIRM SPEED	X				X			
135	CONFIRM ASSIGNED ALTITUDE	X				X		X	
136	CONFIRM ASSIGNED SPEED	X				X			
137	CONFIRM ASSIGNED ROUTE	X				X			
138	CONFIRM TIME OVER REPORTED WAYPOINT	X				X			
139	CONFIRM REPORTED WAYPOINT	X				X			
140	CONFIRM NEXT WAYPOINT	X				X			
141	CONFIRM NEXT WAYPOINT ETA	X				X			
142	CONFIRM ENSUING WAYPOINT	X				X			
143	CONFIRM REQUEST	X				X			
144	CONFIRM SQUAWK	X				X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
145	CONFIRM HEADING	X				X			
146	CONFIRM GROUND TRACK	X				X			
147	REQUEST POSITION REPORT	X				X			
148	WHEN CAN YOU ACCEPT [altitude]	X				X		X	
149	CAN YOU ACCEPT [altitude] AT [position]	X				X			
150	CAN YOU ACCEPT [altitude] AT [time]	X				X			
151	WHEN CAN YOU ACCEPT [speed]	X				X			
152	WHEN CAN YOU ACCEPT [direction][distanceOffset] OFFSET	X				X			
153	ALTIMETER [altimeter]	X		To PFD		X			
154	RADAR SERVICES TERMINATED	X				X			
155	RADAR CONTACT [position]	X				X			
156	RADAR CONTACT LOST	X				X			
157	CHECK STUCK MICROPHONE [frequency]	X				X		X	
158	ATIS [atisCode]	X				X			
159	DOWNLINK ERROR	X				X		X	
160	(system message, no display)	X				X		X	
161	(system message, no display)	X				X			
162	SERVICE UNAVAILABLE	X				X		X	
163	(system message, no display)	X				X			
164	WHEN READY	X				X			

UM No.	Message Element	787 Compatible	787 LOAD	787 DIAL	787 COND	777 Compatible	777 LOAD	MK II Compatible	MK II LOAD 744 & 733
165	THEN	X				X		X	
166	DUE TO TRAFFIC	X				X			
167	DUE TO AIRSPACE RESTRICTION	X				X			
168	DISREGARD	X				X			
169	[freetext]	X				X			
170	[freetext]	X				X			
171	CLIMB AT [verticalRate] MINIMUM	X				X		X	
172	CLIMB AT [verticalRate] MAXIMUM	X				X		X	
173	DESCEND AT [verticalRate] MINIMUM	X				X		X	
174	DESCEND AT [verticalRate] MAXIMUM	X				X		X	
175	REPORT REACHING [altitude]	X				X			
176	MAINTAIN OWN SEPARATION AND VMC	X				X			
177	AT PILOT'S DISCRETION	X				X			
178	(message not supported)								
179	SQUAWK IDENT	X				X		X	
180	REPORT REACHING BLOCK [altitude] TO [altitude]	X				X			
181	REPORT DISTANCE [toFrom] [position]	X				X			
182	CONFIRM ATIS CODE	X				X			
183	FREE TEXT							X	