# MIAMI CONTROLLER-PILOT DATA LINK COMMUNICATIONS SUMMARY AND ASSESSMENT

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## Abstract

The Controller-Pilot Data Link Communications (CPDLC) Build 1 system was operational from October 7, 2002 until September 30, 2004. The system was fielded as a limited-use operational capability in the Miami Air Route Traffic Control Center and surrounding airspace, as a cooperative effort among a group of aviation industry stakeholders, including the Federal Aviation Administration (FAA), airlines, avionics manufacturers, and communications service providers. During the two years of operations, four basic services were enabled through the exchange of more than 85,000 digital messages over an International Civil Aviation Organization (ICAO)-compliant Aeronautical Telecommunications Network (ATN). Thirty aircraft participated in these transactions. The system has shown that CPDLC works, and controllers and pilots have responded positively. This paper describes the CPDLC Build 1 system and summarizes the two years of operations, including the expansion of the basic CPDLC Build 1 capabilities through the Value-Added Services initiative. The paper concludes with a compilation of lessons learned and an overall assessment that places the success of the CPDLC Build 1 system in the context of future CPDLC development.

## Introduction

The Federal Aviation Administration's (FAA's) Controller-Pilot Data Link Communications (CPDLC) Build 1 system began Initial Daily Use (IDU) at the Miami Air Route Traffic Control Center (ARTCC) on October 7, 2002 and was operated until the scheduled system shutdown on September 30, 2004. CPDLC Build 1 was an application of the International Civil Aviation Organization (ICAO)-compliant Aeronautical Telecommunications Network (ATN) and used Very High Frequency (VHF) Digital Link (VDL) Mode 2 air/ground subnetwork to transmit digital messages between air traffic controllers and pilots in appropriately equipped aircraft. In addition to the FAA and the Miami ARTCC, stakeholders included ARINC, American Airlines (AAL), Continental Airlines, Delta Airlines, Atlantic Southeast Airlines (ASA), the United States Air Force (USAF), Rockwell Collins, and Teledyne Controls. Computer Sciences Corporation (CSC) was the primary CPDLC Build 1 system development contractor.

CPDLC Build 1 provided four basic services (functions):

- Transfer of Communications (TOC) for directing a pilot to change the assigned voice frequency.
- Initial Contact (IC) for verification of the pilot's assigned altitude, and to let the controller know that the aircraft has been switched and is currently on the frequency.
- Altimeter Setting (AS) for uplinking barometric pressure data.
- Menu Text (MT) for uplinking a pre-defined set of free-text messages.

These services were invoked through five dialogue (message) types: Contact; Monitor, usually combined with Confirm Assigned Level (CAL); "independent" CAL; Altimeter Setting; and Menu Text.

CPDLC Build 1 was planned as the first step in an evolution of data link capabilities that would eventually provide data link services to all centers through a series of builds intended to keep pace with similar developments in Europe. The FAA CPDLC Build 1 program was based programmatically, operationally, and technically on the concept of operations and architecture of EUROCONTROL's Preliminary Eurocontrol Test of Air/Ground Datalink (PETAL) II program. The Build 1 / PETAL II relationship had multiple levels of cooperation among elements of the FAA and EUROCONTROL CPDLC offices. The principal venue for exchange was through the PETAL Integration Team with ancillary exchanges through ICAO, RTCA, and the Airlines Electronic Engineering Committee (AEEC) activities. A full discussion of the PETAL II program and the FAA / EUROCONTROL collaboration may be found in the PETAL II final report [1]. The technical and operational basis of approval for airspace operators participating in Build 1 were the PETAL Specification [2] and the PETAL Safety and Performance Requirements [3].

CPDLC Build 1 was planned to be a limited duration, single site, en route implementation to prove the viability of CPDLC procedures and capabilities, to be followed by the national deployment of CPDLC Build 1A. However, in April 2003, the FAA's Joint Resources Council (JRC) decided to defer CPDLC Build 1A, but directed the CPDLC team to prepare a Sustainment Plan for continued Build 1 operations in Miami. The Sustainment Plan [4] was prepared in July 2003 and included plans for the resolution of existing operational issues and the implementation of program refinements. Key among the latter included expanding existing capabilities at little or no cost through Value-Added Services.

Ultimately, a programmatic decision, for reasons other than operational or technical deficiencies, led to the decision to terminate CPDLC Build 1 operations in Miami after two years. However, the FAA Air Traffic Organization (ATO) is currently formulating its plans for a national CPDLC program to be implemented in the En Route Automation Modernization (ERAM) timeframe.

This paper describes the CPDLC Build 1 system and summarizes the two years of operations from IDU on October 7, 2002 to the scheduled shutdown on September 30, 2004, including the expansion of the basic CPDLC Build 1 capabilities through the Value-Added Services initiative. The paper concludes with an overall assessment which includes a compilation of lessons learned and places the success of the CPDLC Build 1 system in the context of future CPDLC development.

## Summary of CPDLC Build 1 Operations

Throughout the CPDLC Build 1 operational period, The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) collected operational data and produced metrics that displayed the operational utilization and technical performance of the system. The metrics served as the basis for evaluation of CPDLC Build 1 performance. The metrics were updated monthly and presented to the FAA CPDLC program office and other stakeholders.

The CPDLC metrics were primarily based on data recorded by the Data Link Application Processors (DLAP) at the Miami ARTCC and forwarded to CAASD in Atlantic City, New Jersey for processing, using built-in and custom-developed data reduction and analysis tools. Selected metrics that describe CPDLC Build 1 operations are presented below.

The primary metric that describes CPDLC operational utilization is the number of CPDLC flight legs and the number of operational transactions (controller-pilot communications) conducted for those flights over time. A flight leg is defined as a flight with single departure and arrival points. The transactions were counted from the five message types listed above for the four services: TOC, IC, AS, and MT. Figure 1 summarizes CPDLC Build 1 operations by showing the number of flight legs that used CPDLC and the number of transactions each month. Since IDU, there has been an average of 2.6 transactions per CPDLC flight leg.

As seen in Figure 1, monthly use of CPDLC was quite variable due to a number of factors, including:

- The number of CPDLC-equipped aircraft available. American Airlines was the launch airline for initial participation in CPDLC Build 1. They had 12 aircraft equipped at IDU, and reached their planned complement of 25 aircraft in September 2003. A relatively small percentage of flights were flown by the USAF in a Lear 35, and approximately 72 flights were flown by Continental Airlines, which started using CPDLC on a limited basis in March 2004. In addition, there were a few test and certification flights by Delta and ASA, respectively.

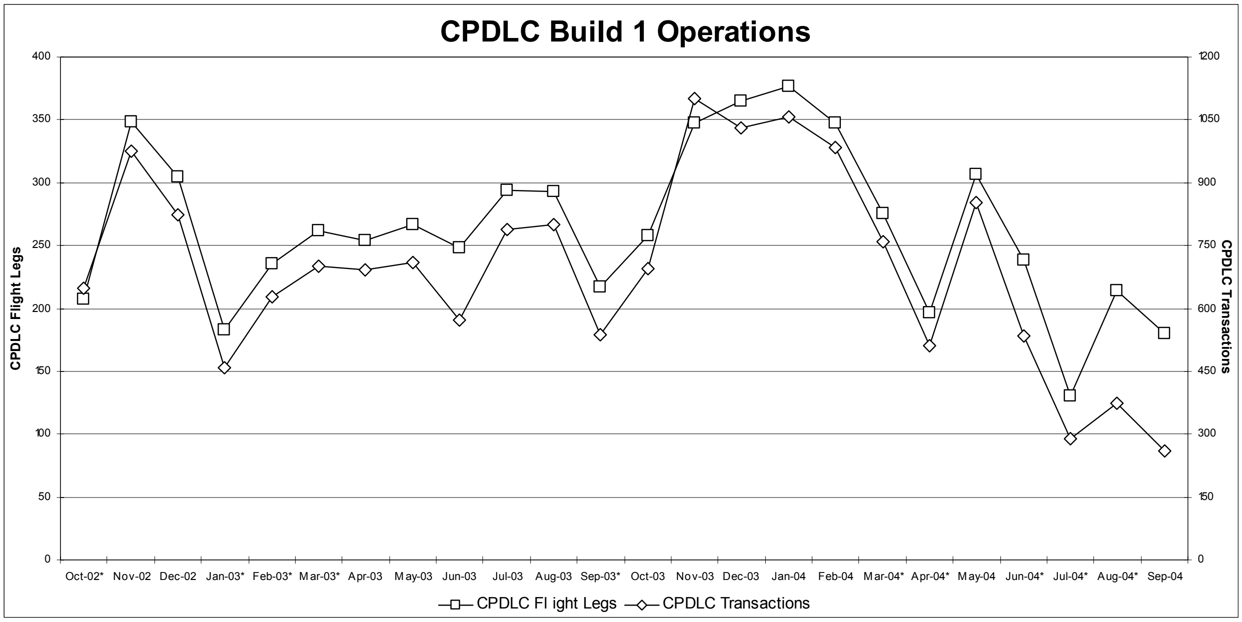


**Figure 1. CPDLC Build 1 Operations (October 2002 to September 2004)**

- Missing days due to unscheduled outages or missing data. Although the system was reliable, there were periods when the system was shut down. There were also days when the data was not available from Miami ARTCC. The months that had less than a full month of operational use are indicated on the x-axis by "*" in Figure 1.
- Seasonal scheduling. The increases in November 2003 through March 2004 indicate a typical increase in scheduled flights to Miami, although the overall increase was limited in the previous year due to the above two factors.
- Introduction of Value-Added Service. The use of MT for direct route clearances may have provided additional incentive for pilots to use CPDLC. Those additional messages increased the number of transactions per flight leg, which reached a maximum of 3.1 in November 2003.
- Announcement of the termination of CPDLC Build 1 in June 2004.

Figure 2 shows the distribution of operational messages that were sent between controllers and pilots since IDU. About 70 percent of the CPDLC transactions were for TOC. These are reflected in Figure 2 through Contact messages and Monitor messages, which were usually combined with CAL messages to verify the aircraft's assigned altitude. Note that "independent" CAL messages (i.e., not associated with TOC) were not used after June 2004.

One of the anticipated benefits of CPDLC was the reduction of voice channel congestion. Estimated equivalent voice times were assigned to CPDLC transactions based on similar transactions by voice. These times vary from six seconds for an AS message to 14 seconds for a TOC using

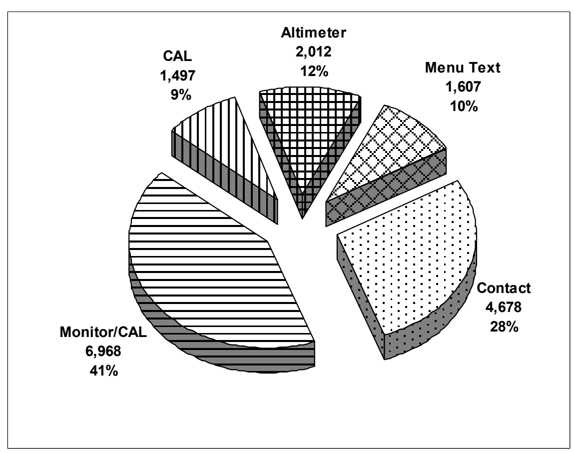


**Figure 2. Distribution of CPDLC Messages by Transaction Type**

Monitor/CAL, and roughly equaled six CPDLC messages per minute of voice time. The estimated savings since IDU was almost 2,800 minutes (see Table 1). Since the voice time estimates do not include some of the inefficiencies of today's simplex channel voice communications, such as blocked or repeated transmissions, the savings estimate may be conservative. When sufficient numbers of aircraft are equipped, this reduction in voice communications is anticipated to improve the level of service that the controller team can provide, as they can use the additional available voice channel time to issue other instructions, and in addition may allow the sector team to handle more aircraft than they do currently.

Table 1 summarizes the CPDLC Build 1 operations.

**Table 1. Summary of CPDLC Build 1 Operations at Miami ARTCC**

| Metric | Value |
| --- | --- |
| Total Number of Flight Legs Flown Using CPDLC | 6,349 |
| Number of Operational Transactions | 16,762 |
| Average Number of Transactions per Flight Leg | 2.6 |
| Average Flight Legs per Day | 9.2 |
| Highest Daily Number of Flight Legs – February 8, 2003 | 26 |
| Total Uplinks and Downlinks* | 85,271 |
| Mean Transaction Time for all Message Types (seconds)[#] | 34.3 |
| Mean Transit Delay (seconds, based on one-half uplink round trip time) | 1.7 |
| Estimated Total Voice Channel Occupancy Time Saved (minutes) | 2,787 |

* Includes uplink messages and downlink responses, as well as Logical Acknowledgements (LACKs) for each, and one-way System Management Messages

[#] Mean value varied by message type from 22.6 seconds for AS to 44.4 seconds for Monitor/CAL

## Expansion of CPDLC Build 1 Capabilities through Value-Added Services

In CPDLC Build 1, there were no messages relating to the change of trajectory of the aircraft (in-flight clearances). Furthermore, FAA procedures for Build 1 precluded use of such messages [5]. After coordination among the user community and the FAA, a proposal was made to modify the MT Service to allow simple clearances as the first of the Value-Added Services.

After some preliminary evaluations, the use of MT was expanded to include direct route clearances as a Value-Added Service starting on November 4, 2003. These messages required only procedural changes, including a temporary procedure, not advisable in a widely deployed system, of pilot voice readback. The messages were in the form: "CLEARED DIRECT *fix(es)* /READBACK/".

Voice readback was only a temporary solution to mitigate hazards, and was only acceptable in Miami because of limited equipage and limited duration. If voice readback was used at higher equipage levels, the voice frequency would soon become more difficult to manage than it is today.

To create the clearances, supervisory personnel at Miami Center could adapt the MT Library associated with the MT Service. This had the potential to provide a virtually unlimited set of new MT free-text messages for controller use. Figure 3 illustrates how Direct Route Clearance MT messages were correlated with MT Referents and assigned to a sector(s) for display on the controller screen. It shows the MT Referent, an abbreviated description, and the full message text as it would be displayed to the pilot when the MT referent was activated.

The controller had a maximum of ten MT Referents that could be displayed at a time on the Display System Replacement (DSR) Menu List. This list was static and could not be changed by the controller. The associated abbreviated text shown in column three of the MT Library was also displayed next to the referent on the DSR as a reminder. Upon uplink by the controller using the ground end system, the CPDLC end system in the aircraft was used to activate, and display to the pilot, the uplinked text message from column four of the MT Library, on the cockpit Multi-Function Control and Display Unit.

The procedure required the pilot to accept the clearance (if operationally acceptable) by sending a WILCO message, and in addition to read it back over the voice frequency to ensure the integrity of the message contents. Acknowledgement by the controller completed the transaction.

An evaluation by the FAA's Independent Operational Test and Evaluation organization,

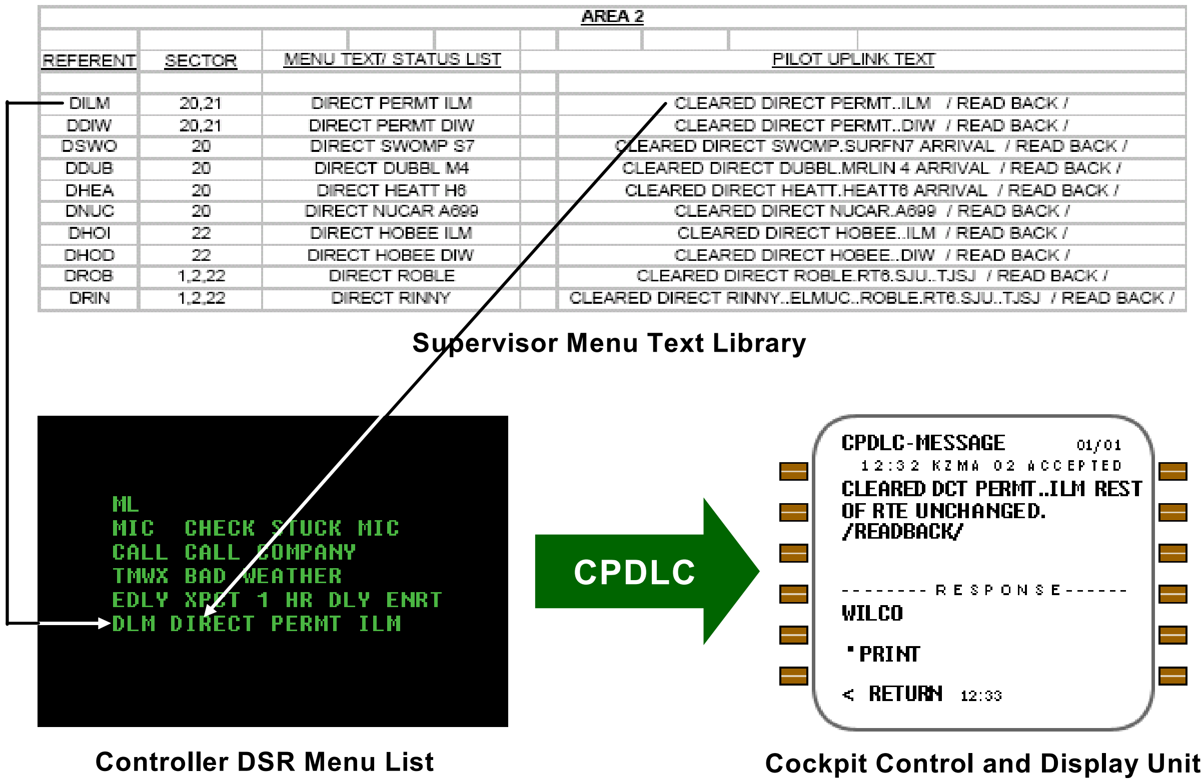


**Figure 3. CPDLC Build 1 "Direct Route" Clearance System Displays**

which was conducted shortly after this Value-Added Service was started, noted the increased usage of CPDLC, because of the introduction of direct route clearance messages, and that there were no anomalies or corrupted data reported [6]

Overall, the expanded use of MT messages for the "Cleared Direct" Value-Added Service increased the use of CPDLC by almost 13 percent since November 2003. The complement of MT messages increased from six percent to 14 percent of all CPDLC messages sent during that time. (Note that Figure 2 indicates the percentage of MT messages since IDU). Table 2 summarizes the use of MT messages for direct route clearances.

**Table 2. Summary of Direct Route Clearances using CPDLC (November 4, 2003 to September 30, 2004)**

| Metric | Value |
|---|---|
| Number of Clearances Sent | 847 |
| Number of Flights Receiving Clearances | 750 |
| Percentage of CPDLC Flights Receiving Clearances | 25.2 |
| Number of Different Clearances Issued | 54 |
| Estimated Voice Channel Occupancy Time Saved (minutes) | 141 |

## Summary and Assessment

CPDLC Build 1 was designed to improve communication between controllers and pilots by replacing routine, non time-critical communications that usually clutter voice frequencies during flight. This eases the job of controllers and pilots who could then concentrate on communications regarded as more time-critical, thereby increasing both efficiency and safety. Specifically with CPDLC Build 1, four basic Air Traffic Control functions were automated –

resulting in minimal controller intervention when used. The overall result was that CPDLC reduced traffic on voice frequencies, resulting in less congested channels for tactical use. Although not specifically measured, CPDLC probably reduced workload, enabling the controller to be more proactive in safely separating aircraft.

CPDLC Build 1 was very successful in providing initial data link services in a limited operational environment. To get the most out of CPDLC Build 1 during its two year operational period at the Miami ARTCC, CAASD and other stakeholders, investigated innovative ways to exploit existing capabilities, such as MT messaging for direct route clearances.

Controllers and pilots responded positively to the efficiency and accuracy of this Value-Added Service. Pilots had favorable reactions to the CPDLC Build 1 system as a whole [7], and even continued using the system after program termination was announced. Miami Center expressed a similar view [8], noting that controllers were generally enthusiastic; and summarized the initial benefits to the controller workforce as:

- Increases safety and corrects errors before they become an incident
- Decreases voice channel occupancy time

## *Major Accomplishments*

The successful operation of CPDLC Build 1 in the Miami Center was the result of significant investment by stakeholders and excellent collaboration between the FAA and the aviation industry. The FAA provided the CPDLC Build 1 program with resources, including controllers, flight standards and certification engineers, pilots and test aircraft, system engineers, human factors specialists, and software developers. Specific accomplishments include:

- The FAA and its aviation industry partners implemented the first successful Air Traffic Services, end-to-end, operational, digital data link communications system in the domestic NAS.
- Required avionics for the flight deck were developed, tested and successfully certified in Miami Center airspace by the stakeholders. These avionics were also used by aircraft operators for CPDLC operations at EUROCONTROL's Maastricht Upper Airspace Control Center.
- During the two years of operational use, users experienced no corruption in message content while exchanging 85,271 messages during 6,349 operational flights using the four basic services/functions.
- The three expected benefits cited by the FAA were realized. Those were:
  - Familiarizing controllers and pilots with data link operations
  - Providing pilots with situation awareness via menu text messages
  - Verifying the CPDLC system architecture
- Additional benefits in the areas of reduced controller workload and safety were noted.
  - An estimated 2,787 minutes of voice channel occupancy time were saved for other uses
  - There were no controller operational errors reported attributable to CPDLC
  - There were no pilot deviations reported while using CPDLC
- ARINC consistently met or exceeded their performance goals for network availability of 99.9 for Florida Sectors and 99.4 for Caribbean sectors.
- CPDLC Build 1 risk mitigation process, including that used for the Value-Added Services, provided a basis for reducing the risk of implementing a nationwide system.

## *Major Lessons Learned*

CPDLC Build 1 provided a unique opportunity to learn about the operation of CPDLC and other systems that involve multiple stakeholders. The major lessons learned compiled from the FAA and other stakeholders are listed below.

- The CPDLC Integration Team, consisting of all active stakeholders, was essential to the successful implementation of Build 1 in Miami Center. The CIT helped to avoid rework of the same time-consuming technical problems by different stakeholders.
- Direct application of FAA resources such as test facilities, test aircraft and test personnel was essential in deploying the end-to-end system.
- During certification flights, aircraft were required to exit Miami ARTCC airspace in order to force avionics to successfully demonstrate transition between sub-networks.

- The CPDLC DLAP worked successfully in the Host Computer System NAS environment at Miami Center, and with one exception (one DLAP failure caused a Host failure; CPDLC was taken offline until the problem was resolved with a software patch) did not interfere with NAS operations.
- Once installed, CPDLC Build 1 was maintainable day-to-day using internal FAA Airway Facilities (ATO Technical Operations) maintenance personnel. However, prime contractor (CSC) support was essential for resolving major technical problems.
- Collecting data from the Build 1 system for use in performance analysis was labor intensive.
- Coordinated Universal Time (UTC) synchronization of all system elements is required.
- Human Factors are critical to acceptability of the system in the cockpit and on the ground.
- Pilot logon procedures and the implementation of the logon function in the avionics must be intuitive to correct the CPDLC Build 1 related inefficiencies.

### *Challenges to Future Deployment*

What was learned and accomplished from CPDLC Build 1 has helped to identify the challenges for deploying a future CPDLC system. The following list highlights some of those challenges that have been gleaned from the Miami CPDLC Build 1 experience.

- Local (NAS) implementations of ATN-compliant CPDLC must be globally harmonized.
- Any future domestic CPDLC system should be presented to the airspace user community as a long-term commitment. A firm basis for planning will encourage equipage, training, and utilization.
- Future U.S. CPDLC systems should address accommodation of FANS-1/A CPDLC to increase pilot participation and overall benefits.
- Development and certification of multiple airborne systems is a major element of the FAA's data link program. The Program Office will need to work closely with both the FAA regulatory organizations (AVR) and airline partners to facilitate and integrate the end-to-end certification and operational approval processes.
- Future plans beyond an initial national deployment of CPDLC should include integration with applicable decision support tools.
- Industry commitment remains vital to CPDLC's progress.

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## Keywords

Controller-Pilot Data Link Communications, CPDLC, Data Link, Value-Added Services, ATN

## Biographies

Mr. Gonda is a graduate of the United States Air Force Academy and was a Command Pilot accumulating more than 30 years of experience in military and civil flight operations and analysis in a wide range of CONUS and worldwide operational and staff assignments. He has over 2600 total flying hours and extensive platform briefing and academic experience. He joined MITRE/CAASD in 2001 and is currently a Lead Systems Engineer serving on the CPDLC and Future Communications Teams.

Since joining MITRE in 1985, Mr. Saumsiegle has primarily supported the FAA and international civil aviation authorities for the test and evaluation of acquired systems. After supporting the Operational Test and Evaluation for the CPDLC Build 1 system, he was responsible for the collection of operational data and preparation of CPDLC metrics. Mr. Saumsiegle received a B.A. degree from Dartmouth College and an M.S. from Old Dominion University.

Captain Blackwell joined American Airlines in 1987 following a 20 year career as an Army Aviator and entered training management as a check airman on the 747 and DC10. In 1990 he became the Technical Pilot responsible for Fleet Modernization Planning and execution. During this time he was also the Chief Pilot for International flight operations and a 767/757 Captain. When American Airlines agreed to join with Euro Control to further the evolution of CPDLC under the PETAL IIe European trials, he put together the team and funding to support this effort, as well as for CPDLC Build 1. He is currently the Director of Operations Engineering at American Airlines. Captain Blackwell received a B.S. from Washington State University and an M.A. from Southern Illinois University.

Frank Longo is a Technical Pilot and B777 Instructor Pilot for Continental Airlines. As Manager of Advanced Communications Development since 1994, he managed the implementation of flight data link on all of Continental's advanced fleet types. Captain Longo was also responsible for the application process, pilot training development and implementation of FANS 1 CPDLC on the B777 and B767 fleets, and was primary program manager during the Miami Build 1 certification and implementation on Continental's B757-300 fleet. He has been an Instructor pilot on the DC-9, MD-80, and B737/757/767/777, and has held FAA Designated Flight Examiner Authority, (Aircrew Program Designee), on these fleet types. Captain Longo started his flying career in 1969 and has over 16,000 hours of flying experience, with over 10,000 hours as Captain on large turbojets.