AIR GROUND DATA LINK VHF AIRLINE COMMUNICATIONS AND REPORTING SYSTEM (ACARS) PRELIMINARY TEST REPORT

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February 1995

DOT/FAA/CT-TN95/66

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City Airport, NJ 08405

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
DOT/FAA/CT-TN95/66			
4. Title and Subtitle AIR GROUND DATA LINK VHF AIRLINE COMMUNICATIONS AND REPORTING SYSTEM (ACARS) PRELIMINARY TEST REPORT		5. Report Date February 1996	
		6. Performing Organization Code ACT-350	
7. Author(s) Albert Rehmann; Jose' D. Mestre, CTA Incorporated		8. Performing Organization Report No. DOT/FAA/CT-TN95/66	
9. Performing Organization Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405		13. Type of Report and Period Covered Technical Note	
		14. Sponsoring Agency Code	
15. Supplementary Notes			

16. Abstract

An effort was conducted to determine actual ground-to-air, and air-to-ground performance of the Airline Communications and Reporting system (ACARS), Very High Frequency (VHF) Data Link System. Parameters of system throughput, error rates, and availability were measured by tabulating statistics of messages ranging from 2 to 150 bytes in length. The intervals of transmission were developed based on anticipated air traffic service (ATS) requirements for tactical air traffic control (ATC) messages and their associated replies.

Overall, the average round trip message delay fell in the range of 10 to 20 seconds, with 5 out of approximately 2300 messages lost.

Aeronautical Radio Inc. (ARINC) did not endorse these tests, indicating that the Federal Aviation Administration (FAA) tests did not take advantage of the capabilities of the ACARS network which has been optimized for airline use.

17. Key Words		18. Distribution Statement	
ACARS VHF Data Link Data Link		This document is available to the public through the National Technical Information Service, Springfield, VA 22161	
19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	36	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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EXECUTIVE SUMMARY

An effort was conducted to determine actual ground-to-air, and air-to-ground performance of the Airline Communications and Reporting System (ACARS), Very High Frequency (VHF) Data Link system. Parameters of system throughput, error rates, and availability were measured by tabulating statistics of messages ranging from 2 to 150 bytes in length. The intervals of transmission were developed based on anticipated air traffic service (ATS) requirements for tactical air traffic control (ATC) messages and their associated replies.

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1. OBJECTIVE OF THE TESTS.

1.1 DESCRIPTION.

Demonstrate that the Airlike Communications and Reporting System (ACARS) Very High Frequency (VHF) Data Link is robust enough to satisfy Air Traffic System (ATS) applications performance requirements. Through flight tests with ACARS avionics and the Aeronautical Radio Incorporated (ARINC) system, specific parameters that characterize the system quality of service (QOS) were experimentally examined.

1.2 DEFINITIONS OF QOS PARAMETERS.

Parameters of QOS applicable to this evaluation program are defined in this section.

1.2.1 Transit Delay.

This is a measure of the time interval beginning with message composition at the source machine, and ending with the receipt and recognition of the message at the destination machine.

In this test, transit delay was measured separately for the uplink and downlink paths.

Based on data reported by ARINC, expected transit times are:

Average Transit Delay for Downlinks:	9 seconds
Average Transit Delay for Uplinks:	12 seconds *

* Note: 3 seconds attributed to polling the ground stations.

Transit Delay is affected by:

a. Type of the message:
   i. length
   ii. Type
b. Type of radio
c. Channel utilization

1.2.2 Residual Error Rate.

This parameter is a measure of lost or garbled messages, expressed as a fraction of the total sent in the sampling period.

ARINC document D00110, “Message Integrity Across the ACARS Network,” defines the domains in which undetected errors occur and the probability of occurrence.

Based on data reported by ARINC, end-to-end integrity with error correction is:

- Parity Check for Character
- Frame Level Cyclic Redundancy Check (CRC) $P_e = 10^{-6}$
- Transport Layer CRC $P_e = 10^{-8}$
- Properly Selected Transport Layer CRC $P_e = 10^{-11}$

End-to-end data integrity is affected by:

a. Type of the message:
   i. message length
   ii. Type
b. Error detection and protection codes used

2. TEST ENVIRONMENT.

2.1 TESTS CONDUCTED.

2.1.1 QOS Evaluation.

Send M series of N messages each T seconds and compute the transit delay of each message. Series will differ in length of the message, and include message lengths of 55, 110, and 220 characters. Each message was time tagged according to the format DD:HH:MM:SS, when the message was transmitted by the communications management unit (CMU). Time tagging was provided by a function within the management unit (MU), and is intended to mark the time of transmission of the message.

The number of messages sent within a series varied from 180 messages to 1,020 messages.

2.1.2. Residual Error Rate.

Examine the message set described in section 2.1.1. above in post-test analysis, to determine by comparison of log files, the ratio of unsuccessful transmissions.

For each message sent and received, CRC was calculated and compared to the message contents.

2.2 INSTALLED SOFTWARE CAPABILITIES.

Software functionality was developed for the ACARS tests which were conducted in March 1992. The software has the following capabilities:

2.2.1 Time Stamp.

Every message, sent or received by the ground equipment has its own valid time stamp. Time stamps generated by the ground equipment were compared to the MU generated time stamps in the analysis of transit delay.

2.2.2 Logout Files.

Every event within the ground equipment (either outgoing or incoming), including messages, acknowledgments received, control information, etc., was automatically stored on disk files when the event was displayed on the ground station control console.

2.2.3 Free Text.

A capability was provided to enable the transmission of free text messages up to 220 characters in length, containing data, control information, or any other text. An example format is shown in figure 1.

Format: send < destination station > < user text >

Example: send n39 *** FAA TECH CENTER DEC TEST ***

which sends to the line:

```
QU DDLXCXA
.ACYXGXA 062311
CMD
/AN N39 /AP ACY
- QUACYXGXA ~FAA TCH *** FAA TECH CENTER DEC TEST *** BBOA
```

where BBOA is the computed CRC of the message.

FIGURE 1. EXAMPLE MESSAGE FREE TEXT

2.2.4 Loopback Messages.

When software in the MU detected the sequence of characters “tilde4” (~4) in a specific portion of the message, it automatically sends the message back to the originator.

The ground station at the Technical Center also has the capability to send loopback messages to the MU installed on the aircraft and store the replies for analysis. An example format is shown in figure 2.

Format: loopback < station > <times> @ <interval> <user text>

Example: loopback n39 3@5 *** FAA TECH CENTER DEC TEXT ***

which will send to the line:

QU DDLXCXA
.ACYXGXA 062313
CMD
/AN N39 /AP ACY
- QUACYXGXA ~4[L00PBACK 004:00000:0699923635]
*** FAA TECH CENTER DEC TEST *** FFA6

wait 5 seconds and send:

QU DDLXCXA
.ACYXGXA 062314
CMD
/AN N39 /AP ACY
- QUACYXGXA ~4[LOOPBACK 004:00001:0699923640]
*** FAA TECH CENTER DEC TEST *** 72El

wait 5 seconds and send:

QU DDLXCXA
.ACYXGXA 062314
CMD
/AN N39 /AP ACY
- QUACYXGXA ~4[L00PBACK 004:00002:0699923645]
*** FAA TECH CENTER DEC TEST *** lFOB

FIGURE 2. EXAMPLE MESSAGE LOOPBACK TEST

The same sequence, tilde4, was also recognized by the ground equipment to cause a loopback to the avionics. All messages were time tagged and appended with a CRC sequence just prior to being looped back.

To prevent the ground station from looping back messages if not desired, the following command is available: set loopback ~4 off

2.2.5 Error Control.

To detect messages, undetected by ACARS, or to detect errors in the case where the message is corrupted in transmission, the ground station had the capability to compute and append CRC codes to each message.

The following commands enable these capabilities:

set arinc on

which applies the polynomial: $x^{16}+x^{15}+x^{l3}+x^{5}+x^{3}+x^{1}+1$

set International Telephone and Telegraph Consultative Committee (ccitt) on

which applies the polynomial: $x^{16}+x^{12}+x^{5}+1$

Note: The probability of an undetected error is greater if the polynomial applied at the transport layer is the same used at the link layer (CCITT).

The error control, if enabled computes the CRCs of every message to be sent, regardless of the type of message, regular or loopback type.

2.2.6 Flow Control.

In order to prevent excessive queuing in the ARINC network due to message overloading (see appendix A), flow control software capabilities have been included in both air and ground end systems. A sliding window protocol was used for flow control, that prevents more than five messages from queuing in the previous loopback message that have not been echoed by the peer equipment. In case of overload, and if no echo is received, transmission of new messages is postponed until a message is received or the corresponding validity timer of the message expires.

2.3 HARDWARE DESCRIPTION.

a. Ground Terminal

- Digital DEC Station 2100, Digital Ultrix Operating System
- Air Land Systems SA-300 Air Land Equipment
- Racal-Milgo 122-RALA Modem

b. Avionics

- Teledyne Controls Management Unit (MU), ARINC Characteristic 724
- Interactive Display Unit (IDU)
- Collins VHF Radio, ARINC Characteristic 716

- Long Ranger FP/PLUS Loran-C Receiver (not used)
- Ziatech STD-80 Bus Personal Computer, STD-DOS Operating System Emulates Digital Flight Data Acquisition Unit (DFDAU)

3. FLIGHT TESTS SCHEDULES.

3.1 ITINERARY AND DURATION OF TESTS.

See figure 3 for definition of NYC-DCA-CHI corridor.

March 9: Flight to Boston, Albany, Atlantic City
Duration: 3 hours, 14 minutes

March 10: Flight to Norfolk, Charleston, Atlantic City
Duration: 3 hours, 14 minutes

March 11: Flight to Cincinnati, Dayton, Cleveland, Atlantic City
Duration: 5 hours 1 minute

March 12: Flight to Chicago, Atlantic City
Duration: 4 hours, 4 minutes

3.2 TESTS PERFORMED.

March 9:	300 55-character messages	(3 series)
	200 110-character messages	(2 series)
March 10:	300 55-character messages	(3 series)
	180 110-character messages	(2 series)
March 11:	340 55-character messages	(4 series)
	300 110-character messages	(3 series)
March 12:	398 55-character messages	(4 series)
	300 110-character messages	(3 series)
Totals:	1298 55-character messages	
	1020 110-character messages	

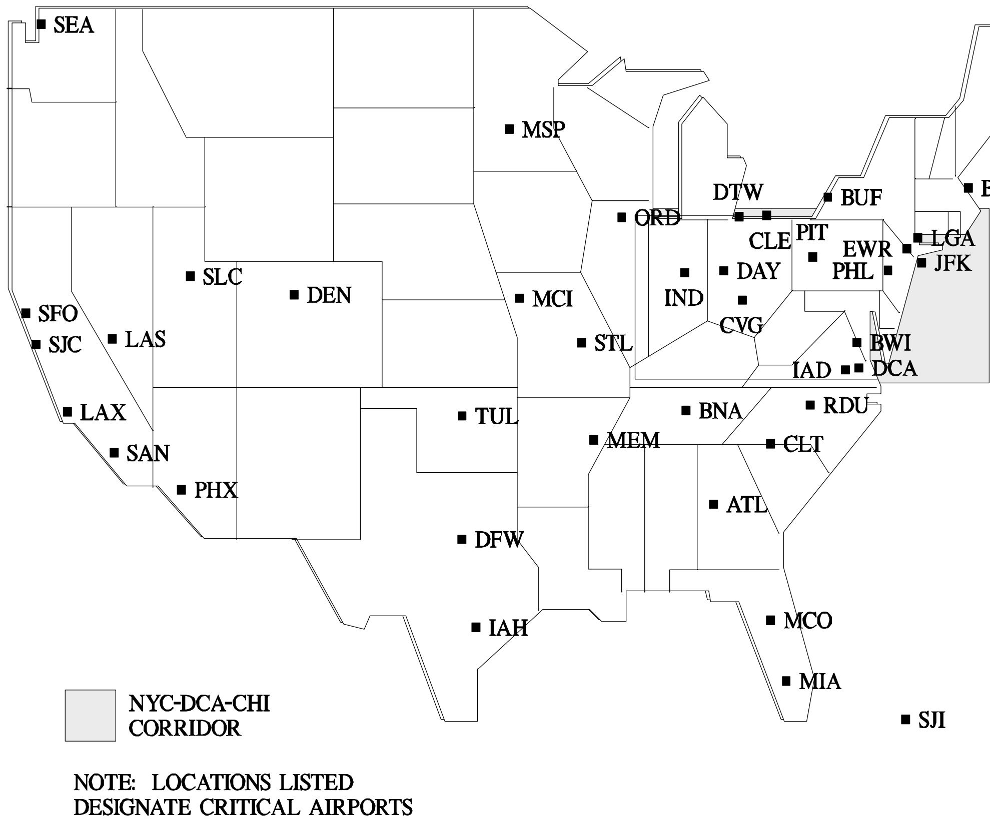

FIGURE 3. ACARS - DEFINITION OF NYC-DCA-CHI CORRIDOR

4. RESULTS.

4.1 QUALITATIVE COMMENTED RESULTS.

The analytical information computed for each series of loopback messages has the following format:

Month: Day:

Series: n/Total

Type: N messages of k characters

Statistics:

Mean: average of the transit delays computed from the sample

Mode: most frequent value observed

St Dev: standard deviation of the transit delays computed from the sample

Minimum: best transit delay observed

Maximum: worst transit delay observed

Problems observed:

Lost: lost messages, if any

Recovery: parameter that measures the capability of the system to restore normal operation after an overloading scenario.

This parameter is computed as the time in seconds elapsed since the maximum delay is reached until the delay decreases to a value equal or smaller than the mean of the sample.

March 9 Series: 1/5

Type: 100 messages of 55 characters

Statistics:

Mean:	12.96 secs
Mode:	7 secs (35 occurrences)
St Dev:	9.21 secs
Minimum:	7 secs (35 occurrences)
Maximum:	52 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 52 to 8: 60 secs

March 9 Series: 2/5

Type: 100 messages of 110 characters

Statistics:

Mean:	21.68 secs
Mode:	12 secs (18 occurrences)
St Dev:	20.02 secs
Minimum:	7 secs (14 occurrences)
Maximum:	95 secs (1 occurrence)

Problems observed:

Lost:	1 messages
Recovery:	From 95 to 19: 220 secs

<u>March 9</u> Series: 3/5

Type: 100 messages of 55 characters

Statistics:

Mean:	12.28 secs
Mode:	7 secs (33 occurrences)
St Dev:	7.12 secs
Minimum:	6 secs (3 occurrences)
Maximum:	37 secs (3 occurrences)

Problems observed:

Lost:	none
Recovery:	From 37 to 9:40 secs

<u>March 9</u> Series: 4/5

Type: 100 messages of 110 characters

Statistics:

Mean:	36.49 secs
Mode:	12 secs (26 occurrences)
St Dev:	42 04 secs
Minimum:	7 secs (4 occurrences)
Maximum:	172 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 172 to 34: 340 secs

<u>March 9</u> Series: 5/5

Type: 100 messages of 55 characters

Statistics:

Mean:	14.25 secs
Mode:	12 secs (32 occurrences)
St Dev:	11.05 secs
Minimum:	6 secs (5 occurrences)
Maximum:	76 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 76 to 13: 100 secs

<u>March 10</u> Series: 1/5

Type: 100 messages of 55 characters

Statistics:

Mean:	32.92 secs
Mode:	7 secs (22 occurrences)
St Dev:	34.03 secs
Minimum:	7 secs (22 occurrences)
Maximum:	122 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 122 to 45: 180 secs

<u>March 10</u> Series: 2/5

Type: 100 messages of 110 characters

Statistics:

Mean:	17.02 secs
Mode:	7 secs (29 occurrences)
St Dev:	14.54 secs
Minimum:	7 secs (29 occurrences)
Maximum:	82 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 82 to 30: 120 secs

<u>March 10</u> Series: 3/5

Type: 100 messages of 55 characters

Statistics:

Mean:	18.20 secs
Mode:	7 secs (29 occurrence)
St Dev:	13.06 secs
Minimum:	6 secs (1 occurrence)
Maximum:	62 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 62 to 18: 160 secs

March 10 Series: 4/5

Type: 100 messages of 55 characters

Statistics:

Mean:	130.85 secs
Mode:	6 secs,7 secs, 171 secs (4 occurrences)
St Dev:	94.56 secs
Minimum:	6 secs (4 occurrences)
Maximum:	372 secs (1 occurrence)

Problems observed:

Lost:	4 messages
Recovery:	From 372 to 128: 420 secs

March 10 Series: 5/5

Type: 80 messages of 110 characters

Statistics:

Mean:	14.60 secs
Mode:	12 secs (35 occurrences)
St Dev:	4.42 secs
Minimum:	9 secs (1 occurrence)
Maximum:	32 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 32 to 13: 60 secs

March 11 Series: 1/7

Type: 100 messages of 55 characters

Statistics:

Mean:	68.95 secs
Mode:	12 secs (8 occurrences)
St Dev:	48.60 secs
Minimum:	7 secs (4 occurrences)
Maximum:	217 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 217 to 63: 300 secs

March 11 Series: 2/7

Type: 100 messages of 55 characters

Statistics:

Mean:	29.23 secs
Mode:	12 secs (12 occurrences)
St Dev:	16.92 secs
Minimum:	7 secs (S occurrences)
Maximum:	77 secs (2 occurrences)

Problems observed:

Lost:	none
Recovery:	From 77 to 27: 100 secs

March 11 Series: 3/7

Type: 100 messages of 110 characters

Statistics:

Mean:	33.58 secs
Mode:	12 secs (17 occurrences)
St Dev:	25.68 secs
Minimum:	7 secs (7 occurrences)
Maximum:	118 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 118 to 23: 180 secs

March 11 Series: 4/7

Type: 100 messages of 110 characters

Statistics:

Mean:	18.92 secs
Mode:	12 secs (28 occurrences)
St Dev:	10.66 secs
Minimum:	7 secs (4 occurrences)
Maximum:	55 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 55 to 13: 80 secs

March 11 Series: 5/7

Type: 100 messages of 110 characters

Statistics:

Mean:	34.92 secs
Mode:	7 secs (22 occurrences)
St Dev:	37.74 secs
Minimum:	7 secs (22 occurrences)
Maximum:	162 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 162 to 58: 240 secs

March 11 Series: 6/7

Type: 100 messages of 5S characters

Statistics:

Mean:	21.96 secs
Mode:	12 secs (14 occurrences)
St Dev:	16.99 secs
Minimum:	6 secs (7 occurrences)
Maximum:	87 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 87 to 12: 160 secs

March 11 Series: 7/7

Type: 40 messages of 55 characters

Statistics:

Mean:	16.08 secs
Mode:	12 secs (27 occurrences)
St Dev:	9.65 secs
Minimum:	12 secs (27 occurrences)
Maximum:	57 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 57 to 13: 80 secs

<u>March 12</u> Series: 1/7

Type: 100 messages of 55 characters

Statistics:

Mean:	19.81 secs
Mode:	12 secs (29 occurrences)
St Dev:	10.98 secs
Minimum:	7 secs (6 occurrences)
Maximum:	52 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 52 to 13: 60 secs

<u>March 12</u> Series: 2/7

Type: 100 messages of 55 characters

Statistics:

Mean:	13.77 secs
Mode:	7 secs (30 occurrences)
St Dev:	9.15 secs
Minimum:	6 secs (11 occurrences)
Maximum:	52 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 52 to 12: 60 secs

<u>March 12</u> Series: 3/7

Type: 100 messages of 55 characters

Statistics:

Mean:	11.58 secs
Mode:	7 secs (54 occurrences)
St Dev:	8.80 secs
Minimum:	6 secs (7 occurrences)
Maximum:	57 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 57 to 8:84 secs

<u>March 12</u> Series: 4/7

Type: 100 messages of 110 characters

Statistics:

Mean:	16.57 secs
Mode:	12 secs (21 occurrences)
St Dev:	9.74 secs
Minimum:	7 secs (15 occurrences)
Maximum:	58 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 58 to 13:80 secs

<u>March 12</u> Series: 5/7

Type: 100 messages of 110 characters

Statistics:

Mean:	20.92 secs
Mode:	7 secs (25 occurrences)
St Dev:	24.97 secs
Minimum:	7 secs (25 occurrences)
Maximum:	127 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 127 to 19:180 secs

<u>March 12</u> Series: 6/7

Type: 100 messages of 110 characters

Statistics:

Mean:	34.32 secs
Mode:	7 secs (23 occurrences)
St Dev:	42.42 secs
Minimum:	7 secs (23 occurrences)
Maximum:	162 secs (2 occurrences)

Problems observed:

Lost:	none
Recovery:	From 162 to 23: 220 secs

March 12 Series: 7/7

Type: 98 messages of 55 characters

Statistics:

Mean:	14.30 secs
Mode:	12 secs (27 occurrences)
St Dev:	9.67 secs
Minimum:	6 secs (4 occurrences)
Maximum:	56 secs (1 occurrence)

Problems observed:

Lost:	none
Recovery:	From 56 to 12: 120 secs

Totals: Type: 2318 messages of 55/110 characters

Statistics:

Mean:	28.01 secs
Mode:	12 secs (450 occurrences = 19.45 %)
St Dev:	38.79 secs
Minimum:	6 secs (42 occurrences)
Maximum:	372 secs (1 occurrence)

Problems observed:

Lost:	5 messages
Recovery:	Best: From 37 to 9: 40 secs
	Worst: From 372 to 128: 420 secs

4.2 DISCUSSION OF RESULTS.

Figure 4 shows the combined total of messages transmitted between aircraft and ground station peer entities, over the 4-day period.

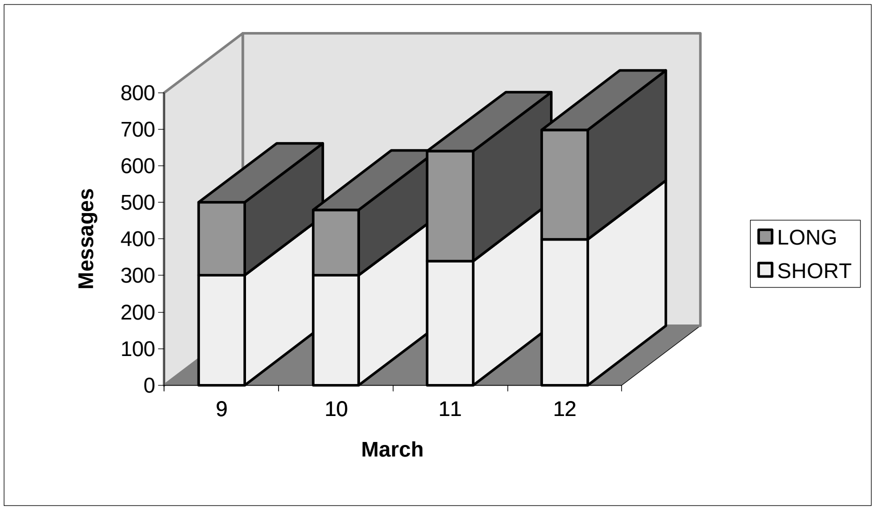

FIGURE 4. TESTS PERFORMED

Figure 5 shows the bin distribution of one-way delay times (in seconds), by day, over the 4-day period. All data samples are combined into figure 5. Most of the message transit times fall into the 11- to 20-second bin range, with the second highest incidence in the 6- to 10-second range.

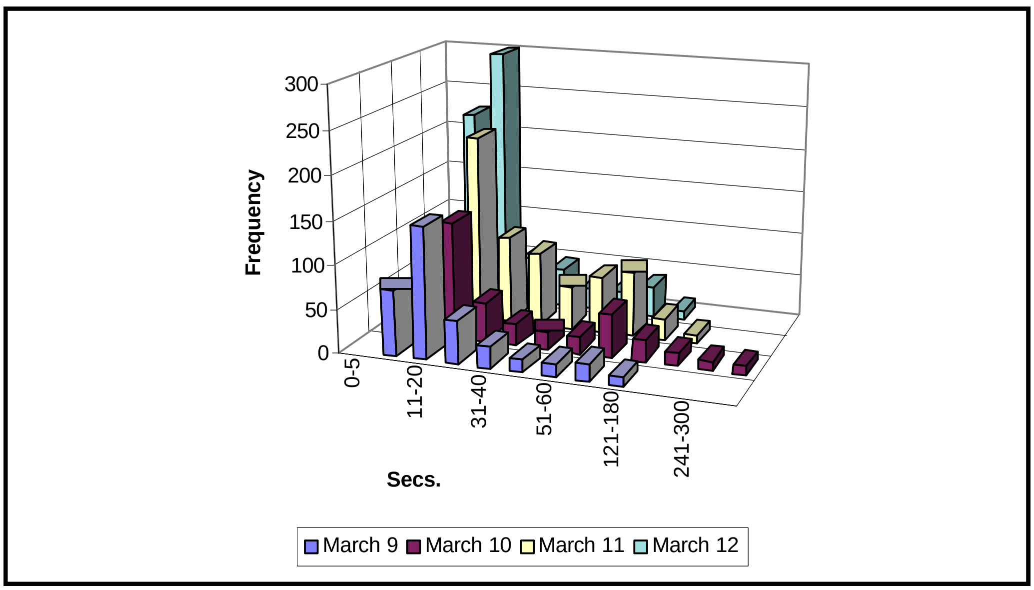

FIGURE 5. DISTRIBUTION OF FREQUENCY OF OCCURRENCE OF ONE-WAY DELAY TIMES

Figure 6 shows in a different presentation, accumulated delay data by day, for the 4-day period.

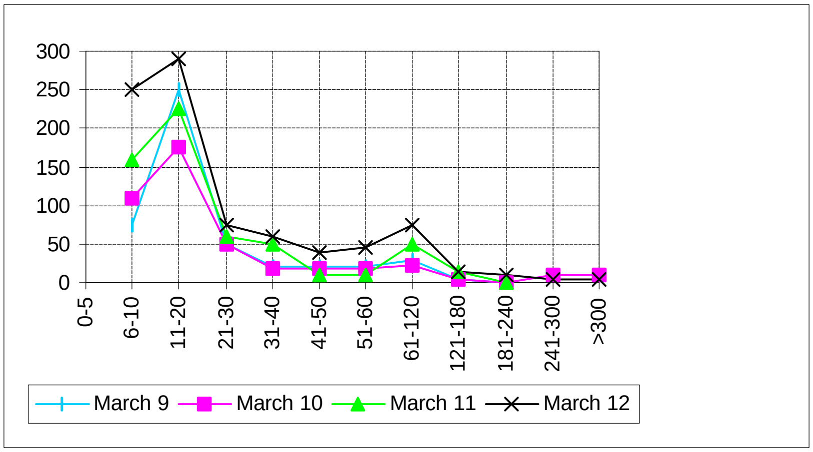

FIGURE 6. AVERAGE MESSAGE DELAY

Figure 7 shows one-way delay times, in seconds, averaged over each series. The coordinate references on the horizontal axis refer to the day and series number within the day. For example, s9.1 refers to the first message series on March 9, 1992. Average series delays in excess of 120 seconds occurred on March 10, 1992, during a flight to Norfolk, Virginia. These extended transit times were the result of queuing, even with flow control procedures in place.

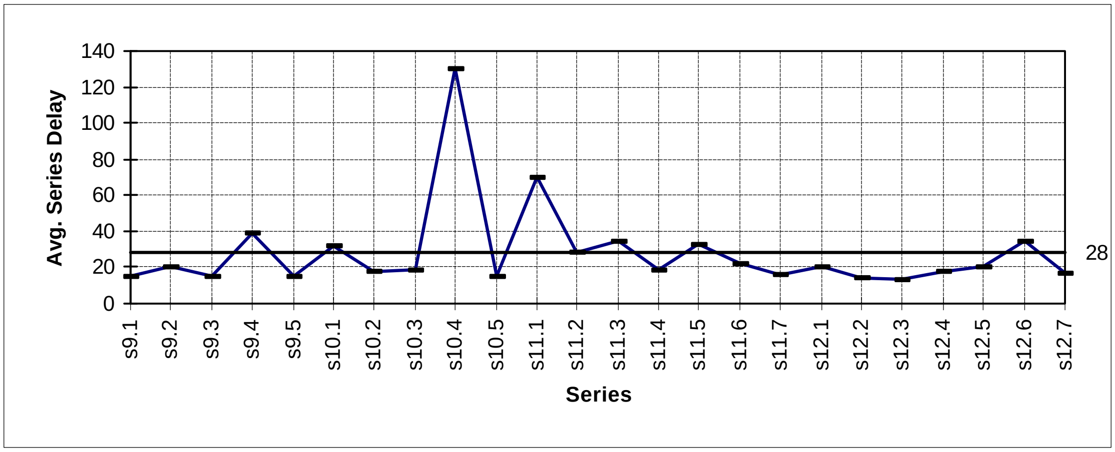

FIGURE 7. AVERAGE SERIES DELAY

Figure 8 shows the standard deviation of transit times for each series, expressed in the same format as figure 7. The shape factor of the curve resembles figure 7.

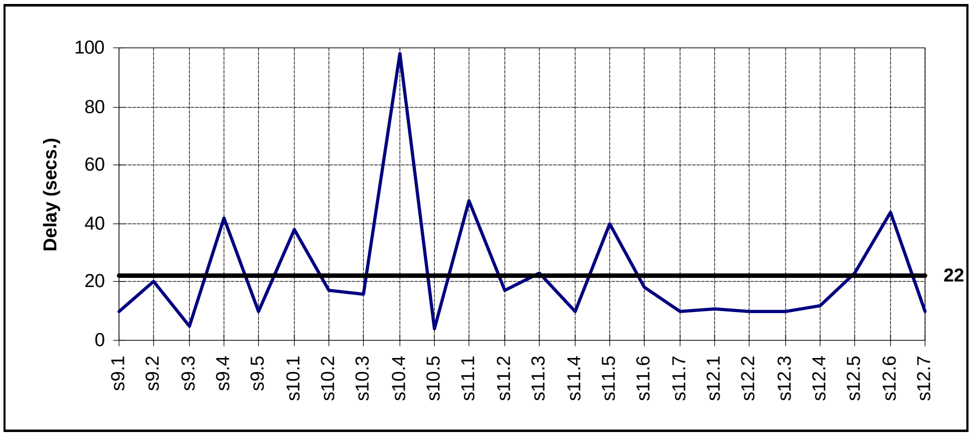

FIGURE 8. STANDARD SERIES DEVIATION

5. SUMMARY OF RESULTS.

One-way transit times in the range of 6 to 20 seconds formed the preponderance of data. Longer delay times were the result of queuing within the ACARS network. Queuing occurred when a message was delivered to the network for transmission before the previous message was closed out.

ARINC reports that message queuing represents misuse of the network, and represents an enormously high amount of traffic. ARINC correspondence on the subject is contained in appendix A.

Short message lengths (55 characters) chosen by the FAA Technical Center test personnel were believed to represent typical ATS message lengths after necessary protocol and routing information were added. Longer message lengths (110 bytes) were believed to represent longer messages of flight information or weather.

A total of 5 messages were lost out of a total of 2,318 messages transmitted. Of these, 1 message was 110 characters in length, and 4 were 55 characters in length. All 4 of the lost 55 character messages were lost during the same flight which occurred on March 10, 1992.

6. CONCLUSIONS.

Data contained in this report provides a performance indicator of the performance of the Airline Communications and Reporting System (ACARS) network. Although commercial avionics were used in this test, Aeronautical Radio Inc. (ARINC) does not endorse the results, stating that the network was not used in a manner for which it is designed.

APPENDIX A
ARINC PHASE 4 TEST REPORT

RFAA/TELEDYNE 724 ACARS AVIONICS
AQP PHASE 4 FLIGHT TEST
23 MARCH 1992

GENERAL:

ARINC conducted a Phase 4 test audit for the VHF ACARS avionics aboard an FAA/CV-580 aircraft (reg. ID. 3) on 11 March 1992. The aircraft was being used for Intensive end-to-end Data Link message integrity testing by the FAA Technical Center in Atlantic City, NJ. Rick Olson of the FAA served as the on-board engineer. The aircraft was operated locally in the NJ-NY-MASS area. Limited testing of supported message labels was performed due to the enormous amount of Loop-Back testing being performed.

SUMMARY:

Phase 4 flight testing was conducted on March 11, 1992, for the FAA Teledyne avionics installed aboard the FAA's CV-580/N39 aircraft. Only limited testing of the avionics' supported message labels could be performed due to the intensive FAA Loop-Back testing during the audit. In spite of the poor signal strengths received during the course of the audit, the avionics uplink success ratios were sufficiently above the 88%-minimum AQP requirement. However, a significant error occurred with the ACK/NAK protocol exhibited by the avionics. In each case, when an RA/~1 (Uplink Display Message) was initiated for the aircraft, the avionics improperly responded by providing an acknowledgment followed by a nonacknowledgment for the same message. It is unknown if the avionics received any or all of these display messages. In light of this problem, further testing in support of the uplink Labels not tested during this audit is recommended to test the remaining system responses.

An item of interest is discussed in the Problems and Issues Section below concerning the reliability of the rapid Loop-Back-Integrity testing conducted by the FAA during the flight.

MESSAGES OBSERVED:

The following uplink and downlink messages were observed during the audited f1ights:

Label	Sublabel	U/D	Message Type
_DEL	n/a	U	General Acknowledgment
:;	n/a	U	Autotune to New Frequency
RA	~ 1	U	Display Message
RA	~ 2	U	000I Dump
RA	~ 3	U	Memory Dump
RA	~ 4	U	Loop-Back Test
51	n/a	U	GMT Update
54	n/a	D	Voice Go-ahead

Label	Sublabel	U/D	Message Type
_DEL	n/a	D	General Acknowledgment
NAK	n/a	D	Non-Acknowledgment
H1	DF	D	DFDAU Message
Q0	n/a	D	Link Test
Q5	n/a	D	Unable to Deliver Message
RB	~2	D	000I Dump
RB	~3	D	Memory Dump
RB	~4	D	Loop-Back Test Response
52	TXT	D	Free Text Message
51	n/a	D	GMT Update Request

AVIONICS UPLINK PERFORMANCE:

The following uplink success ratios were observed during the audit. These ratios are a measure of the reliability of an Individual message being received by the avionics on the first uplink transmission occurrence. The observed ratios were as follows:

Unsolicited Uplink Successes: 82% (135 Successes/163 Attempts)

Solicited Uplink Successes: 91% (153 Successes/167 Attempts)

Overall Uplink Successes: 87% (288 Successes/330 Attempts)

With the exception of an autotune message (Label :;) sent from ARINC and a DFDAU message discussed in the Problems and Issues section below, all messages were eventually acknowledged by the avionics.

NOTED PROBLEMS AND ISSUES:

A significant problem was observed during this audit with the ACK/NAK protocol. Over the course of the 2-hour/25-minute audit, every RA/~1 (Free Text Uplink) that was Initiated (13 total) was originally ACK'd by the avionics and then NAK'd 5 seconds later. This is indicative of a significant protocol error and is a deviation from AEEC specifications. Once AFEPS received the ACK for the uplinked message, it considered the message sequence complete and freed the buffer for the next uplink message. The messages were effectively lost if not properly buffered by the avionics. It is unknown if the avionics actually processed and displayed the 13 NAK'd uplinks.

Received downlink signal strengths over the course of the audit were generally weak which may have contributed to the uplink success ratios.

Two RA/~4 (Loop-Back) messages were NAK'd during the audit, presumably due to weak signal strengths which were observed before and after the NAK occurrences.

On one occasion, an Hl/DF (DFDAU) uplink was Q5'd and returned to its origin due to the improper usage of the up1ink SMI and internal sub-label combination (DFD/~1) in the format of the input message.

An Issue of Note for the FAA: during the early portion of the audit, while attempting to conduct Phase 4 coordination, a Memory Dump and an 000I Dump uplink were both initiated by ARINC while the avionics was in the process of responding to the first series of Loop-Back testing between the avionics and the FAA Host Processor. The avionics was responding to the 50 Loop-Backs in the command series at 30-second intervals. The avionics handled the memory Dump correctly but it appears that it could not respond quickly enough to accommodate the extra demand of the 000I Dump upon its arrival between Loop-Back responses. A series of 36 failed uplink attempts over a period of 6 minutes was initiated during the time that the avionics was in the process of responding to the 000I and Loop-Back testing simultaneously. All uplinks were eventually acknowledged and responded to by the avionics during this period.

Noting the overloaded condition of the avionics, ARINC decided to assume a passive position and allow the FAA to complete its Loop-Back testing unabated while continuing to collect the audit data which is necessary for ARINC Avionics Qualification.

Because of the nonstandard circumstances of the continuous Loop-Back testing and the acceptable performance of the avionics responding to subsequent Loop-Back testing at even tighter intervals (100 messages at 20-second intervals), these failures were not included in the success ratio calculations above: however, it is recommended that for qualification purposes further testing be performed to include the message labels which were not tested during this flight test.

Since 20-second intervals between messages delivered to a single aircraft is not representative of a typical scenario, data results from the FAA's perspective may be affected. The normal handshake and timeout retransmission intervals of the system could increase the likelihood of message delays and undelivered uplinks.

TEST LIMITATIONS:

Because of the enormous amount of Loop-Back messages being exchanged during the audit, all message label types could not be tested.

ARINC
AERONAUTICAL RADIO, INC.

2551 Riva Road
Annapolis, Maryland 21401-7465

April 23, 1992
File: 07-1-7 FA

Mr. Rick Olsen
Avionics Engineer
FAA Technical Center
Airborne Systems Technology
Branch, ACD-330
Atlantic City Intn'l. Airport
Atlantic City, NJ 08405

Dear Rick:

As a follow-up to our recent phone conversation, I would like to reiterate the following points.

— The Avionics Qualification Policy (AQP) tests on your VHF avionics have not been completed.

— Use of the ARINC operational network for on-line testing is not permitted.

On March 9, 1992 we attempted a phase 4 test of your avionics. This test was incomplete, partially because of the hundreds of loop-back tests that you sent within an unusually short time-frame. We consider any test results that you obtain with this avionics to be invalid until the AQP program is completed.

We are anxious to assist you in your evaluation of data link and would appreciate your timely scheduling of phase 4 testing.

You should understand that we have optimized the ACARS system for standard flight profiles. For instance, the downlink buffer size has been tailored for the number and rate of arrival of downlinks that we have learned to expect from an operational airline flight. When these thresholds are exceeded, alarms to our System Manager are

Completed
4/30/92

generated and if the condition is not corrected, system performance is impacted. This was the case when you transmitted hundreds of loop-back messages on March 9th. Any non-standard use of ACARS must be coordinated with the ARINC System Management Office. Any ACARS use that resembles a stress test will not be permitted without thoroughly evaluating the impact on critical airline operational traffic.

Very truly yours,

J. J. Sullivan
Vice President
Quality Management

pjg

ARINC
AERONAUTICAL RADIO, INC.

2551 Riva Road
Annapolis, Maryland 21401-7465

June 17, 1992
File: 07-1-7 FA

Mr. Rick Olsen
Avionics Engineer
FAA TECHNICAL CENTER
Airborne Systems Technology Branch, ACD-330
Atlantic City International Airport, NJ 08405

Dear Rick:

Attached is the completed Phase 4 AQP test report for the FAA/Teledyne 724 ACARS avionics. As noted in the report, the avionics has a significant error with ACK/NAK response protocol logic. The problem was evident when responding to the RA/~1 and RA/~4 uplink labels. Each RA/~1 message improperly received both an ACK and a NAK for the first block of each uplink message, while each RA/~4 message received an ACK for the first block and both an ACK and a NAK for any additional blocks.

Since multiple responses to a single uplink are not in accordance with any of the AEEC specifications and because they cause system inefficiencies due to the superfluous downlinks and unnecessary uplink retransmissions that occur, we can not approve this release for operation on the ACARS network. Please contact us with scheduling information regarding AQP testing on the next release for this software.

We appreciate you cooperation with the AQP process and believe that your participation is helping to maintain and augment the high degree of network reliability for all ACARS users.

Sincerely,

jgl
cc: Angus McEachen
92-24.FA

SRN# 92-00870
7 MAY 1992

GENERALS

Coordinated Phase 4 testing was conducted on 30 April 1992 for the FAA/Teledyne 724 ACARS avionics. This test was initiated to test system responses which could not be verified during previous flight testing due to the intensive Loop-Back testing being performed by the FAA. The test was ground based and fully coordinated with test engineers at both ARINC (Steve Leger) and the FAATC (Rick Olson) in Atlantic City providing the various supported uplink and downlink message labels.

SUMMARY:

The FAA/Teledyne 724 avionics performed well during the test with the serious exception of the ACR/NAK protocol errors associated with the RA/~1 (Uplink Display Message) and RA/~4 (Loop-Back) uplink message labels noted in prior flight testing. Each RA/~l received both an ACK and a NAK general response downlink for the first uplink block of a single or multi-block uplink, while the RA/~4 received an ACK for the first block and both an ACK and a NAK for any additional blocks. In each case the avionics caused excess use of the available RF resources and suffered adversely (77%) in terms of uplink success ratios due to the multiple uplink retransmissions necessary to deliver each RA/~1,~4 labeled message. An ASCII format floppy disk of the audit data has been forwarded to Rick Olson of the FAA to help illustrate the observed protocol errors. The ACK/NAK problem is a definite protocol error and could in connection with the normal timeout and retransmission intervals of the system affect the uplink data link integrity for the FAA.

MESSAGES OBSERVED:

The following uplink and downlink messages were observed during the audited flights:

Label	**Sublabel**	**U/D**	**Message Type**
_DEL	**n/a**	**U**	**General Acknowledgment**
·;	**n/a**	**U**	**Autotune to New Frequency**
RA	**~1**	**U**	**Display Message**
RA	**~2**	**U**	**OOOI Dump**
RA	**~3**	**U**	**Memory Dump**
RA	**~4**	**U**	**Loop-Back Test**
Cl	**n/a**	**U**	**Display Message**
H1	**DF**	**U**	**DFDAU Message**
S1	**n/a**	**U**	**GMT Update**

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54	n/a	U	Voice Go-ahead
-DEL	n/a	D	General Acknowledgement
NAK	n/a	D	Non-Acknowledgement
F3	n/a	D	Dedicated Transceiver

QC	n/a	D	ON Report
QF	n/a	D	OFF Report
QO	n/a	D	Link Test
Q3	n/a	D	Clock Update Advisory
Q5	n/a	D	Unable to Deliver Message
RB	~2	D	OOOI Dump
RB	~3	D	Memory Dump
RB	~4	D	Loop-Back Test Response
5U	n/a	D	Weather Request
5Z	ACK	D	Manual Acknowledgement
5Z	TXT	D	Free Text Message
5l	n/a	D	GMT Update Request
54	n/a	D	Voice Contact Request

AVIONICS UPLINK PERFORMANCE:

The following uplink success ratios were observed during the audit. These ratios are a measure of the reliability of an individual message being received by the avionics on the first uplink transmission occurrence. The observed ratios were as follows:

Solicited Uplink Successes: 80% (16 Successes/20 Attempts)

Unsolicited Uplink Successes: 76% (36 Successes/47 Attempts)

Overall Uplink Successes: 77% (52 Successes/67 Attempts)

As shown above, the success ratios are below the 80% minimum AQP requirement. The majority of the failed uplink attempts were due to the retransmissions effected by the unnecessarily NAK'd messages. If these extra messages were not included in the success ratio calculations above, the overall uplink success ratio would increase to 96%.

NOTED PROBLEMS AND ISSUES:

The problem noted in previous testing with the ACK/NAK protocol, sending both a positive acknowledgement and a non-acknowledgement downlink as a response for a single uplink, was again evident during this audit.

During the 1.5 hour audit, each of the three RA/~l (Free Text Uplink) messages sent to the avionics was originally ACK'd by the avionics on the first uplink occurrence and then improperly NAK'd five seconds later. Two of these occasions were multiple blocked uplinks. On each of the multi-block uplinks, only the first block received the unnecessary NAK.

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In each case, the second block, while not NAK'd itself, had to be resent due to a five second delay: the first block NAK arriving at AFEPS after the second block had, because of the receipt of the first block ACK, already been sent. Upon receipt of these erroneous NAKs, AFEPS interpreted them to mean that the second block was in error, which caused the second block to be resent unnecessarily.

Each of the six multi-block RA/~4 (Loopback) tests that was initiated during the audit received an ACK for the first block and both an ACK and a

NAK for any subsequent blocks at the same five second delay interval. In each case, the five second delay propagated through the message causing the last block of each message to be resent two to three times.

Both an RA/~2 (OOOI Dump) and an RA~3 (Memory Dump) were observed to operate properly without any additional NAKs attached. These were single block command response uplinks and only tested once.

In summary, The RA/~l messages received an ACK/NAK for only the first block, the RA/~4 messages received an ACK/NAK for any blocks beyond the first. The responses to the RA/~l and RA/~4 uplinks by the avionics are serious deviations from any of the published AEEC standard characteristics and were observed to cause multiple unnecessarY uplink retransmissions.

John Linsenmeyer,
QM/QTST