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**The Thirteenth Meeting of the Regional Airspace Safety Monitoring
Advisory Group (RASMAG/13)**

Bangkok, Thailand, 02 – 05 August 2010

Agenda Item 5: Airspace safety monitoring activities/requirements in the Asia/Pacific Region

CPDLC/ADS-C Data Link Performance Monitoring

(Presented by Pacific Approvals Registry and Monitoring Organization (PARMO))

SUMMARY

This paper provides observed performance measures as specified in the Global Operational Data Link Document (GOLD) from the operational data collected in Oakland and New York oceanic airspace. This analysis includes performance of the Controller Pilot Data Link Communication (CPDLC) and Automatic Dependent Surveillance – Contract (ADS-C).

In addition, a summary of observed errors in the estimated time of arrival at next position contained in ADS-C position reports received at Oakland and New York oceanic centers is presented.

1. Introduction

1.1 This paper provides observed performance measures from the operational data link system at Oakland and New York Oceanic Centers. The purpose of this paper is to present recent observed performance of the data link system.

1.2 The performance data observed from the Controller Pilot Data Link Communication (CPDLC) and Automatic Dependent Surveillance - Contract (ADS-C) systems are measured against the Required Communication Performance (RCP) 240 specification to demonstrate that safety objectives which rely on the communications infrastructure can be met by the aircraft and ground systems.

1.3 This paper also provides summary information on observed errors in the estimated time of arrival at next position contained in ADS-C basic periodic and waypoint change reports. These errors were contained in reports received at both Oakland (ZOA) and New York (ZNY) oceanic centers.

2. Discussion

2.1 The Global Operational Data Link Document (GOLD) provides the guidance material describing the required data points from the FANS 1/A aircraft communications addressing and reporting system (ACARS) messages. The GOLD also describes the calculation process for the actual communication performance (ACP), actual communication technical performance (ACTP), pilot operational response time (PORT), and surveillance latency.

2.2 The ACP is used for monitoring the RCP requirement time allocation for the communication transaction (TRN). The TRN is the portion of the total transaction time that does not include the message composition time or recognition of the operational response. Actual communications technical performance (ACTP) is used to monitor required communication technical performance

(RCTP) time allocations, and pilot operational response time (PORT) is used to monitor the flight deck responder element of the transaction.

2.3 As described in the GOLD, this analysis uses the measurement of transit and response times to those CPDLC uplinks that receive a single Will Comply (WILCO) and/or an Unable response. These messages are considered to be intervention messages critical to the communications used when applying reduced separation standards. Other message types, such as free text queries or information requests, are not included in the analysis because the corresponding longer response time from the flight deck would skew the results. All messages with a WILCO and/or Unable response attribute are assessed. These include communications transfer messages in addition to the typical intervention messages such as climb clearances. The ACP is computed by the difference between the time the uplink message is originated at the air traffic service provider (ATSP) and the time the corresponding response downlink is received at the ATSP.

2.4 The ACTP is computed in three steps. The first step is to estimate the downlink time from the difference between the time stamp on the aircraft-originated downlink message and the ATSP received time. Then, the round trip time of the uplink message is estimated from the difference between the time the uplink message was sent from the ATSP and the receipt of the message assurance (MAS) response for the uplink at the ATSP. The last step is to divide the estimated round trip time by two and add the result to the estimated downlink time. Equation 1 provides the estimate of ACTP:

$$((MAS\ receipt - Uplink\ transmission\ time)/2 + Downlink\ time) \tag{1}$$

2.5 The GOLD also describes the estimation of the PORT latency, which is calculated by the difference between ACP and ACTP. Figure 1, taken from the GOLD, illustrates these measurements.

2.6 Observed Data Link Performance by Media Type

2.6.1. Figures 2 and 3 present the ACP measurement for the messages sent to and from the New York and Oakland Oceanic Centers, respectively, by media (Satellite, VHF, and HF) during the collection period. The numbers of CPDLC messages included in the analysis are shown in the legend of Figures 2 and 3. There were 12,286 satellite, 2,925 VHF, and 24 HF data link messages in the New York data set. There were 64,173 satellite, 2,661 VHF, and 507 HF data link messages in the Oakland data set. Figures 2 and 3 show the estimated ACP for the HF messages do not meet either the 95 or 99.9 percent requirement; however the number of HF messages was relatively small. The ACP for CPDLC messages sent via Satellite and VHF messages meet the 95 percent criteria but fall just below the 99.9 percent criteria.

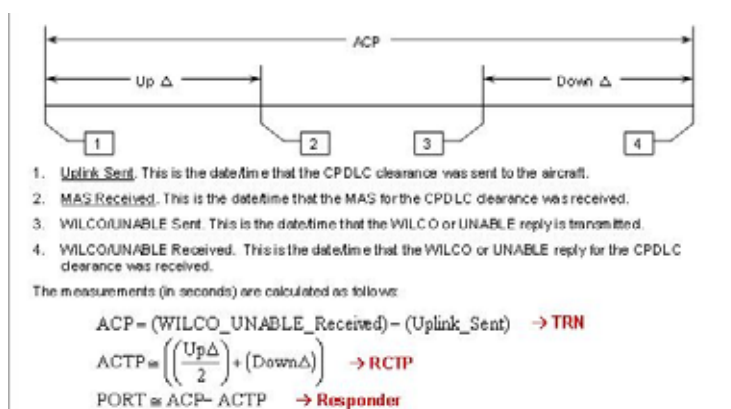


Figure 1. CPDLC transaction calculations (reference GOLD)

2.6.2. The observed 95 percent ACP for all satellite and VHF data link messages in the New York FIR are 149 and 127 seconds, respectively. The 95 percent requirement for ACP is 180 seconds; both the VHF and satellite data link messages are meeting this requirement in New York oceanic airspace. The observed 95 percent level for ACP for all satellite and VHF data link messages in the Oakland

FIR are 76 and 84 seconds, respectively, this observed performance is slightly better than that observed in New York oceanic airspace.

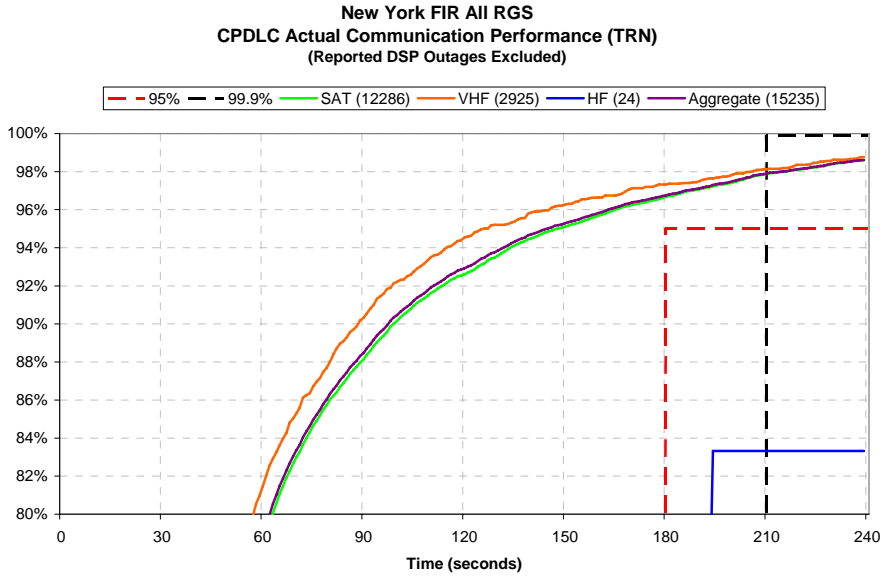


Figure 2. ACP – New York Oceanic Airspace by Data Link Media

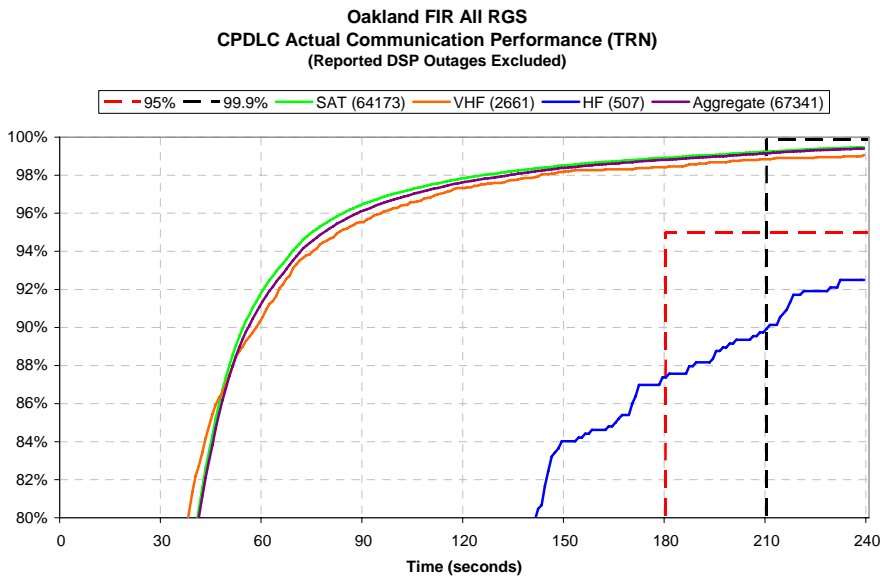


Figure 3. ACP – Oakland Oceanic Airspace by Data Link Media

2.6.3. Figures 4 through 7 present the ACTP and ADS-C measurements, respectively, for messages sent from the New York and Oakland Oceanic Center by media (Satellite, VHF, and HF) during the collection period. Again, the numbers of CPDLC and ADS-C messages used for each measurement are shown in the legend key of the figure. Similar performance by media type is noted for the messages transmitting through HF for the ACTP and ADS-C performance as was noted for the ACP in Figures 2 and 3.

2.6.4. The observed 95 percent level for ACTP for all satellite and VHF data link messages in the New York FIR are 55 and 32 seconds, respectively. The 95 percent requirement for ACTP is 120

seconds; both the VHF and satellite data link messages are meeting this requirement in New York oceanic airspace. The observed 95 percent level for ACTP for all satellite and VHF data link messages in the Oakland FIR are 34 and 31 seconds, respectively, this observed performance is slightly better than that observed in New York oceanic airspace.

2.6.5. The observed 99.9 percent level for ACTP for all satellite and VHF data link messages in the New York FIR are 229 and 135 seconds, respectively. The 99.9 percent requirement for ACTP is 150 seconds; only the VHF data link messages are meeting this requirement in New York oceanic airspace. The observed 99.9 percent level for ACTP for all satellite data link messages in the Oakland FIR is 209 seconds, the ACTP for VHF data link messages did not reach the 99.9 percent level in Oakland oceanic airspace.

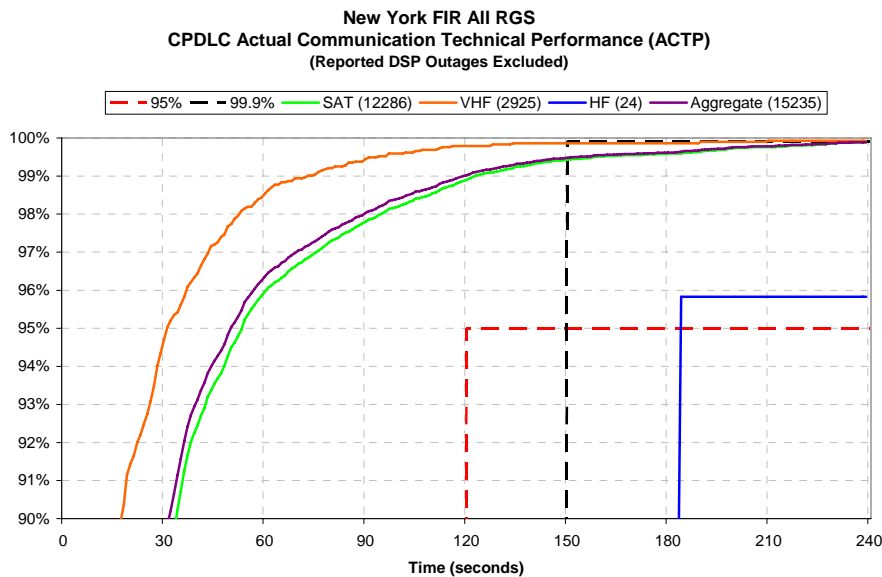


Figure 4. ACTP – New York Oceanic Airspace by Data Link Media

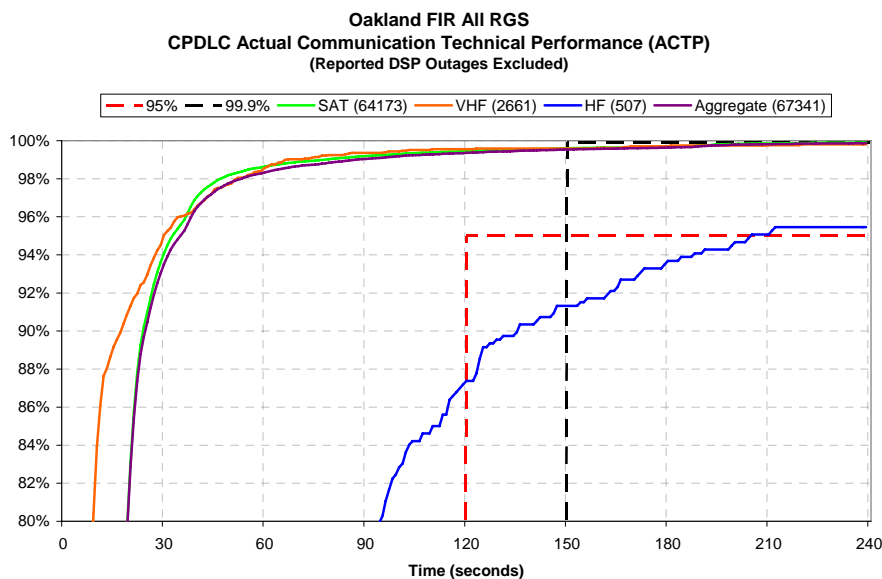


Figure 5. ACTP – Oakland Oceanic Airspace by Data Link Media

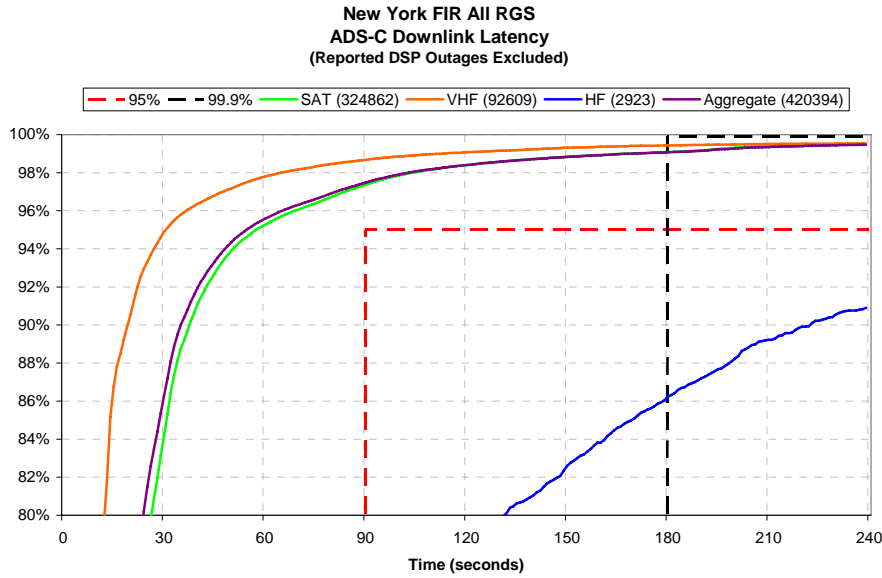


Figure 6. ADS-C Performance – New York Oceanic Airspace by Data Link Media

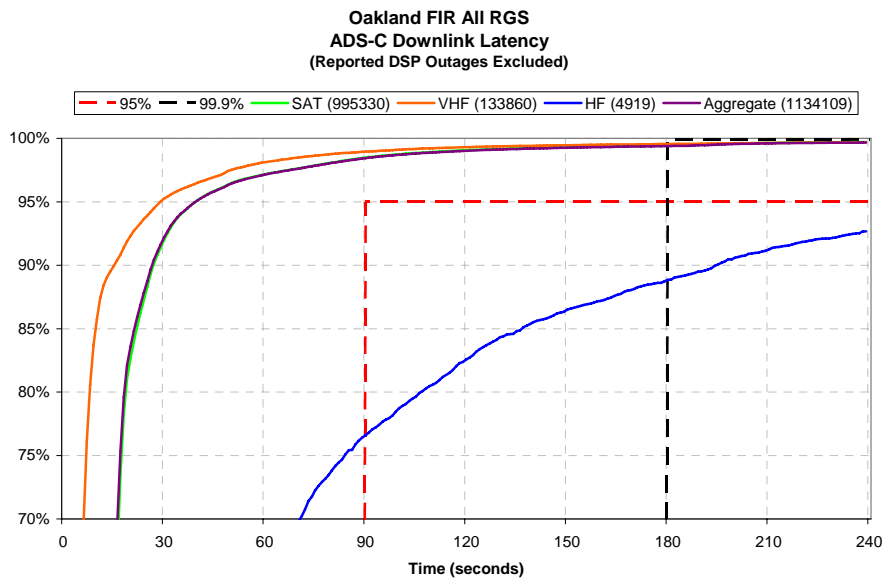


Figure 7. ADS-C Performance – Oakland Oceanic Airspace by Data Link Media

2.6.6. The observed 95 percent level for ADS-C performance for all satellite and VHF data link messages in the New York FIR are 59 and 32 seconds, respectively. The 95 percent requirement for ADS-C performance is 90 seconds; both the VHF and satellite data link messages are meeting this requirement in New York oceanic airspace. The observed 95 percent level for ADS-C performance for all satellite and VHF data link messages in the Oakland FIR are 41 and 30 seconds, respectively, this observed performance is slightly better than that observed in New York oceanic airspace.

2.6.7. Figures 8 through 10 present the New York FIR ACP, ACTP and ADS-C performance by month for the August 2009 through February 2010 time period. Figures 8 through 10 include message performance from by all data link media (Sat, VHF, and HF). The numbers of messages observed during each month are shown in the legend key of each figure. The results in Figures 8 through 10 include all data link sources; satellite, VHF, and HF.

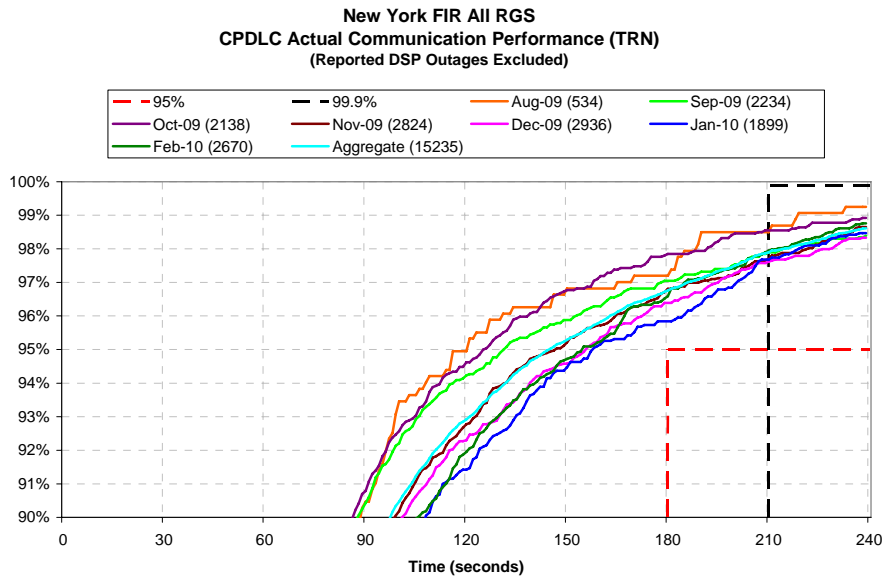


Figure 8. ACP – New York Oceanic Airspace by Month

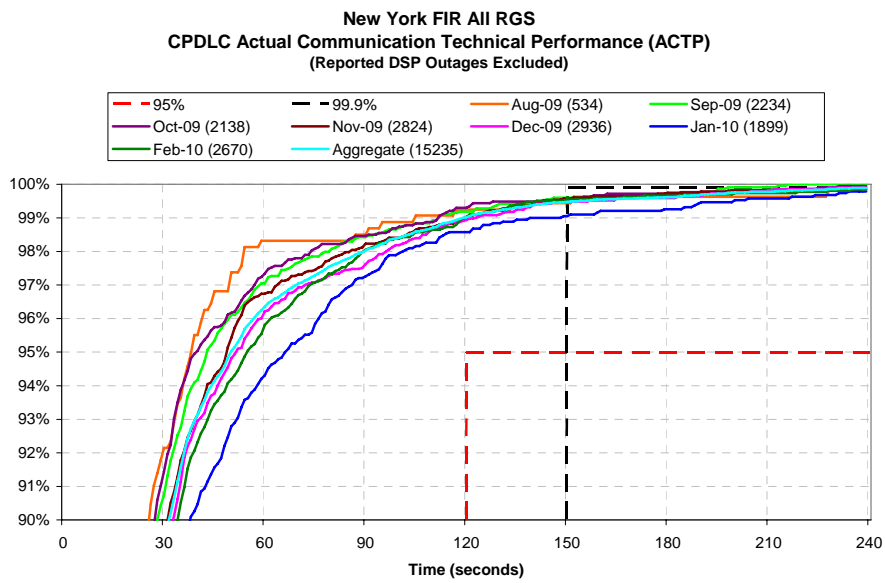


Figure 9. ACTP – New York Oceanic Airspace by Month

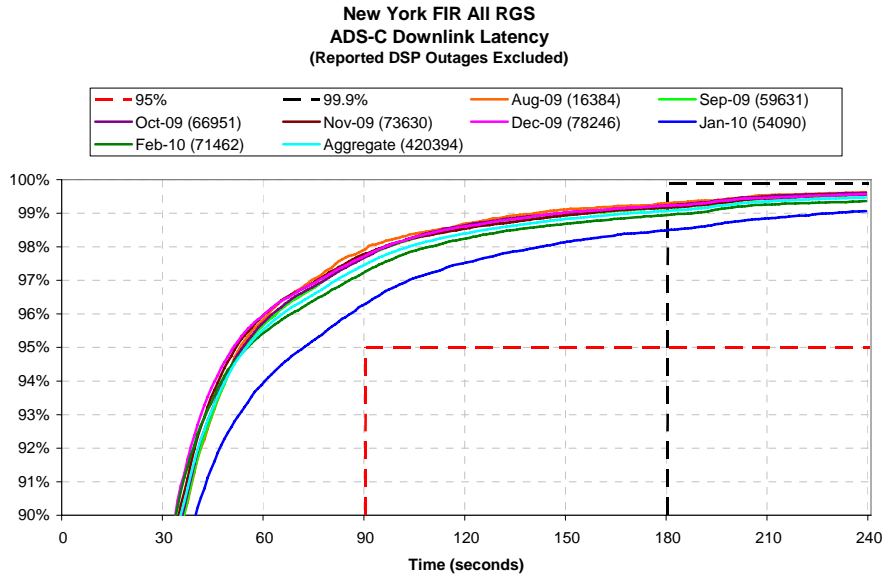


Figure 10. ADS-C Performance – New York Oceanic Airspace by Month

2.6.8. Figures 11 through 13 present the Oakland FIR ACP, ACTP and ADS-C performance by month for the August 2009 through January 2010 time period. Figures 11 through 13 include message performance from by all data link media (Sat, VHF, and HF). The numbers of messages observed during each month are shown in the legend key of each figure. The results in Figures 11 through 13 include all data link sources; satellite, VHF, and HF.

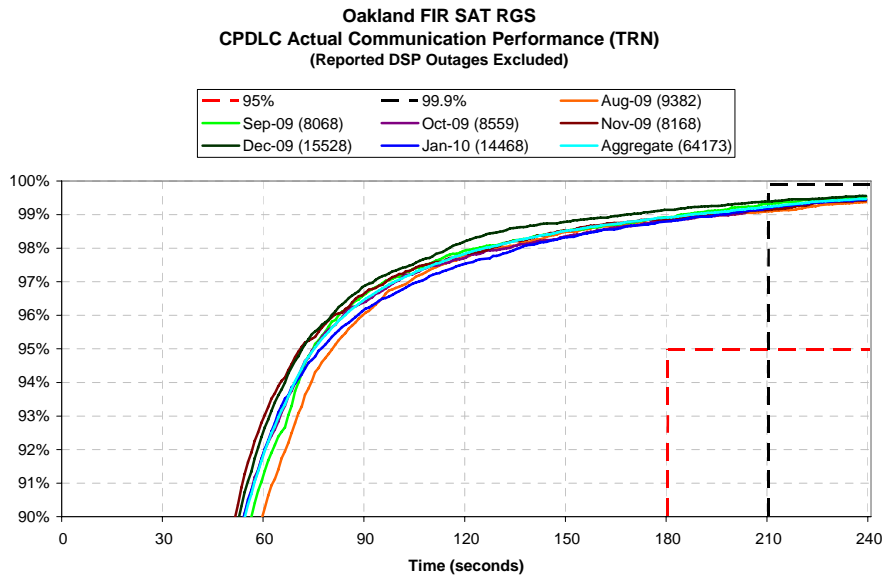


Figure 11. ACP - Oakland Oceanic Airspace by Month

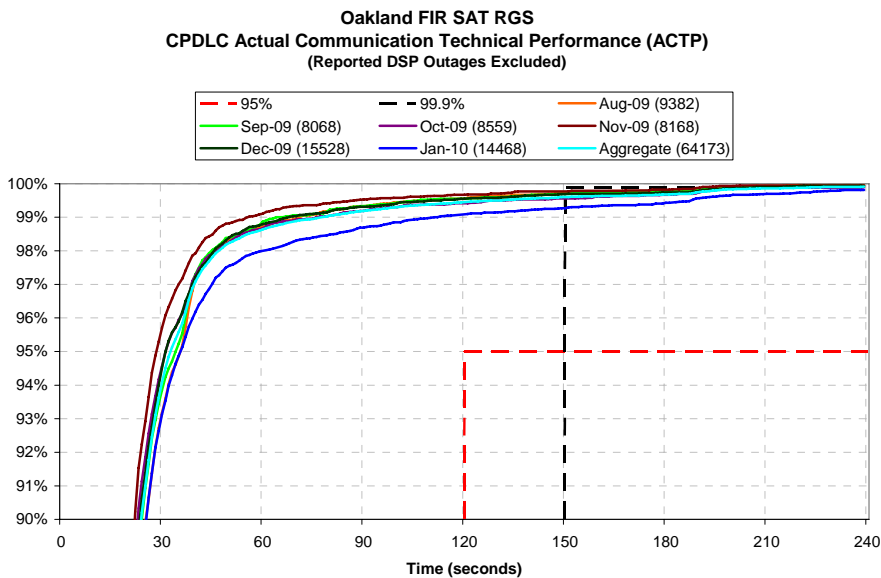


Figure 12. ACTP - Oakland Oceanic Airspace by Month

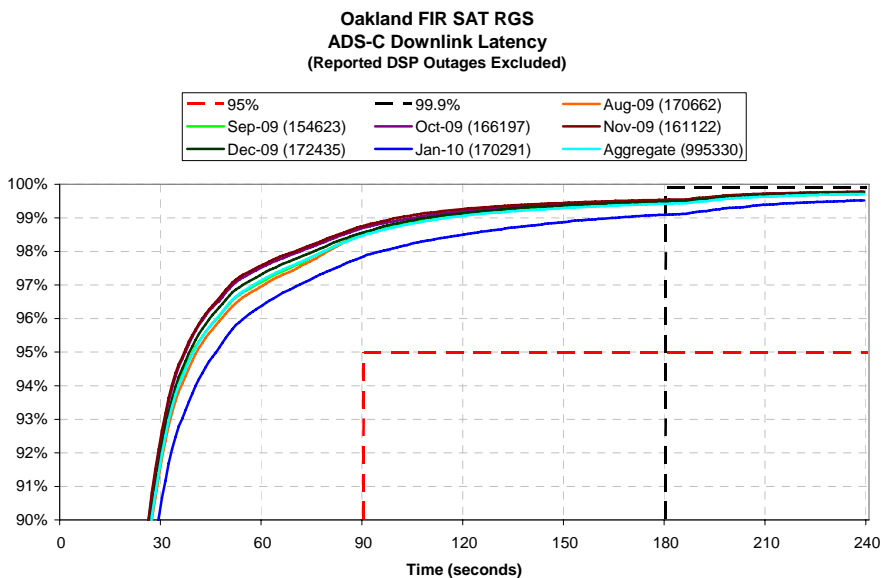


Figure 13. ADS-C Performance - Oakland Oceanic Airspace by Month

2.7 Observed Data Link Performance by Operator

2.7.1. Figures 14 through 17 show the ACP, ACTP, PORT and ADS-C Downlink Latency Charts by operator for the time period August 2009 through February 2010. Figures 14 through 17 include only satellite data link communications and represented observed performance in the New York FIR. Again, the numbers of messages observed during each month by operator are shown in the legend key of each figure. The top 13 operators in terms of message counts are shown in Figures 14 through 17; the operator information is desensitized in the figures.

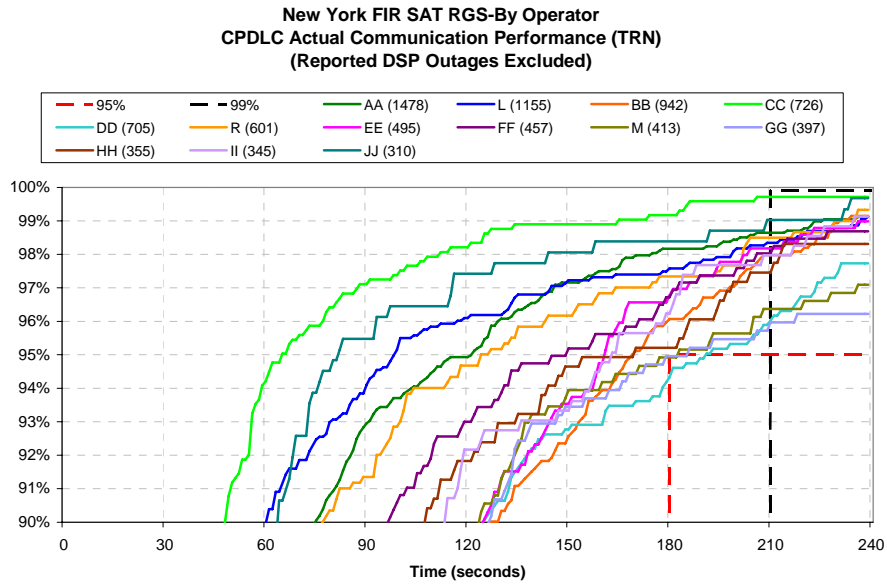


Figure 14. ACP – New York Oceanic Airspace by Operator

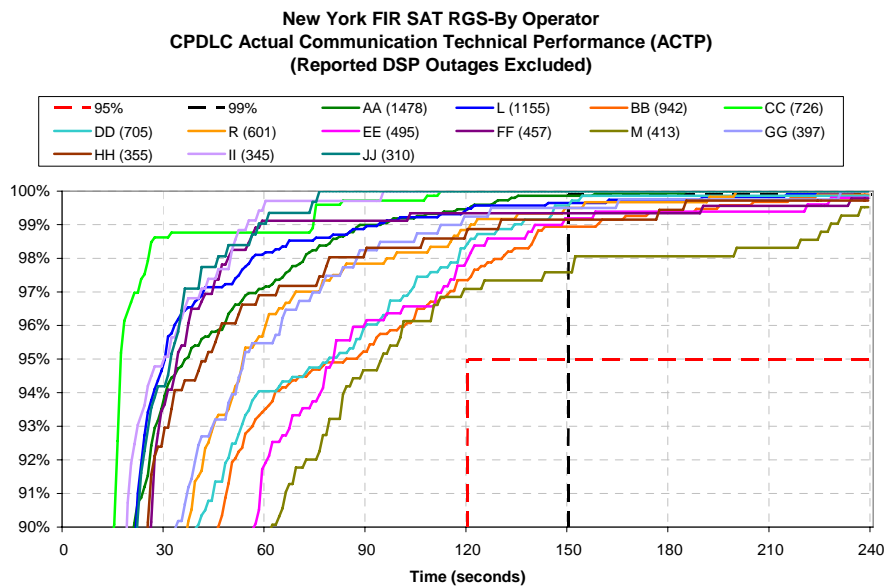


Figure 15. ACTP – New York Oceanic Airspace by Operator

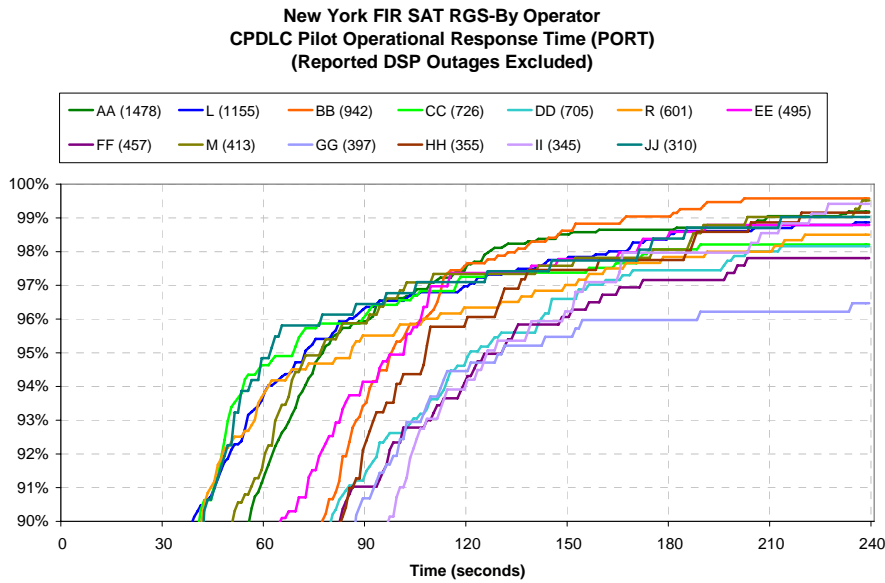


Figure 16. PORT – New York Oceanic Airspace by Operator

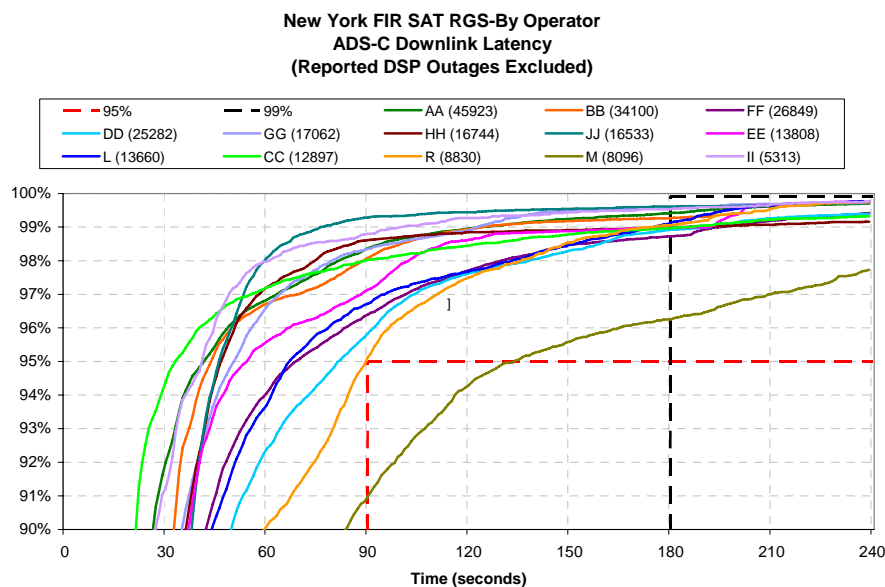


Figure 17. ADS-C Performance – New York Oceanic Airspace by Operator

2.7.2. The observed CPDLC performance by operator for the ACTP shown in Figure 15 meets the 95 percent criteria. However, not all of the operators shown in Figure 14 meet the 95 percent requirement for ACP of 180 seconds. In addition, the observed ADS-C performance for one operator shown in Figure 17 does not meet the 95 percent requirement of 90 seconds.

2.7.3. Figures 18 through 21 show similar data contained in Figures 14 through 17 but for the Oakland FIR. It is noted that the observed ACP, ACTP, PORT and ADS-C performance by operator in the Oakland FIR is slightly better than that observed in the New York FIR.

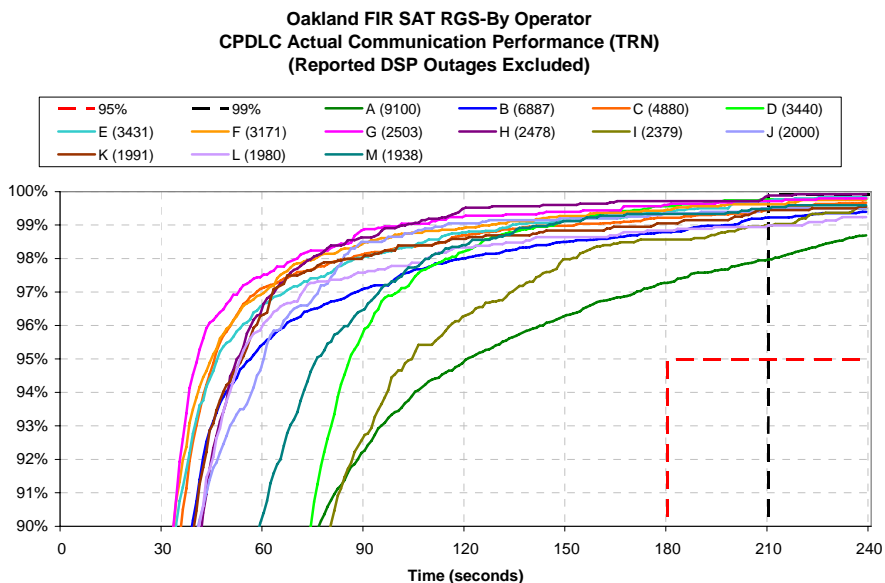


Figure 18. ACP - Oakland Oceanic Airspace by Operator

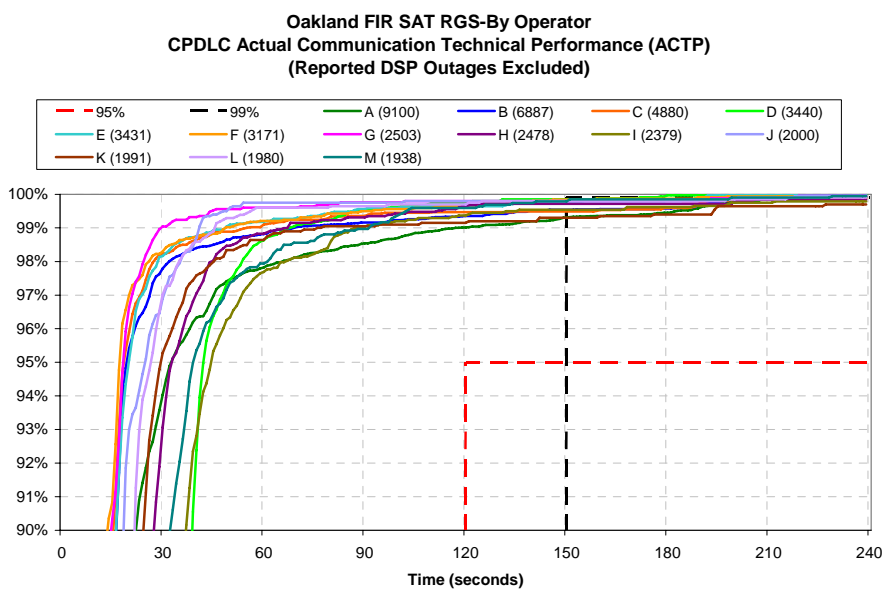


Figure 19. ACTP - Oakland Oceanic Airspace by Operator

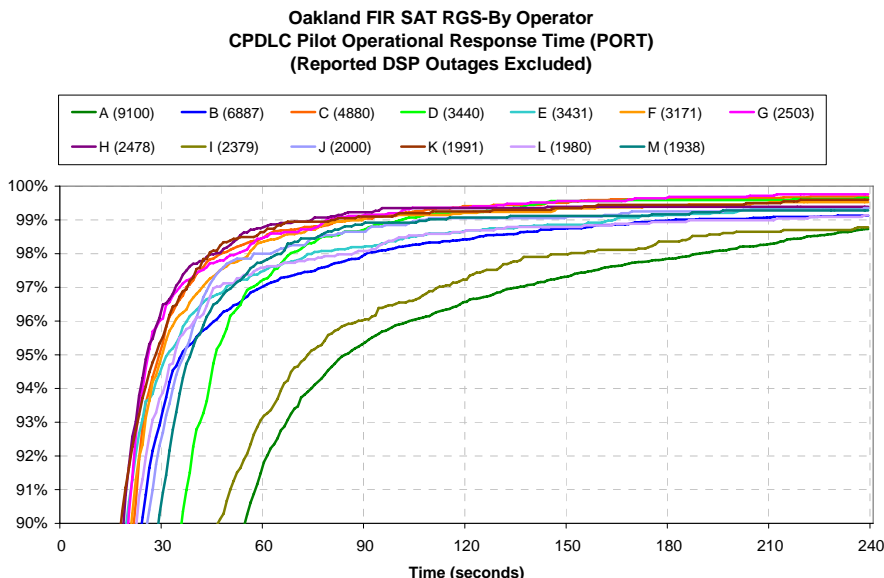


Figure 20. PORT - Oakland Oceanic Airspace by Operator

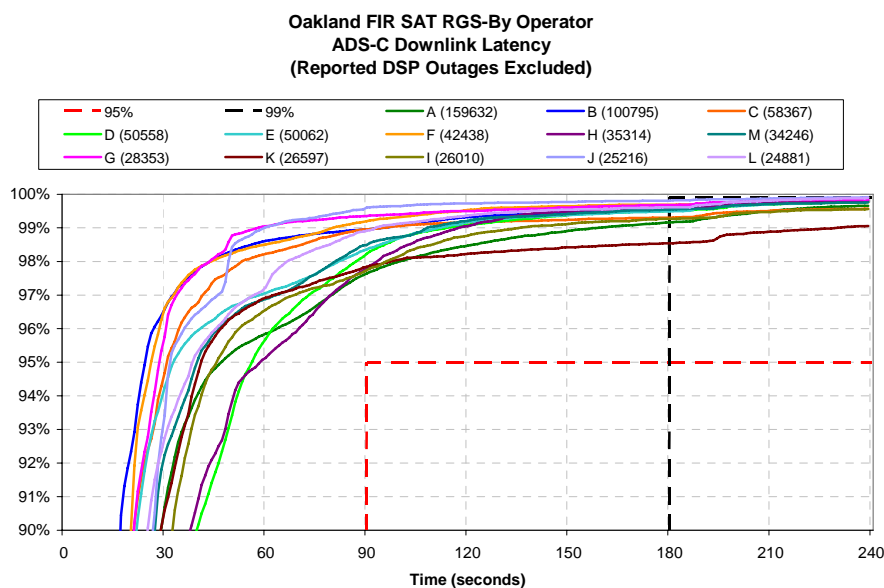


Figure 21. ADS-C Performance - Oakland Oceanic Airspace by Operator

2.7.4. All observed performance by operator in the Oakland FIR for the ACP, ACTP and ADS-C performance shown in Figures 18 through 21 meet the respective 95 percent requirements.

2.8 Observed Data Link Performance by Operator and Aircraft Type

2.9 Figures 22 through 25 show the observed ACP, ACTP, PORT and ADS-C performance for B772 aircraft by operator from the New York FIR. These observations represent only satellite data link communications (e.g. VHF and HF messages were excluded) for the top 8 operators in terms of message counts. Once again, the operator information is desensitized in the figures.

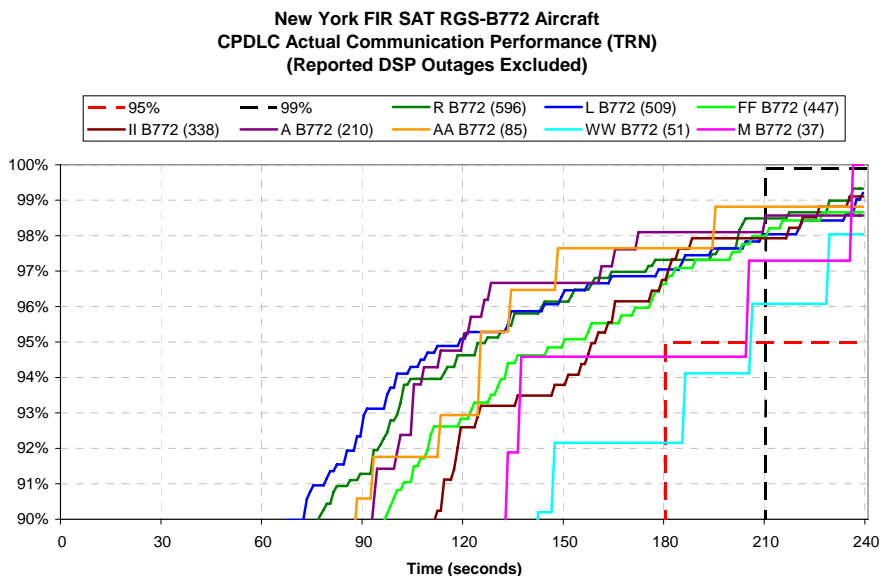


Figure 22. ACP – New York Oceanic Airspace B772 by Operator

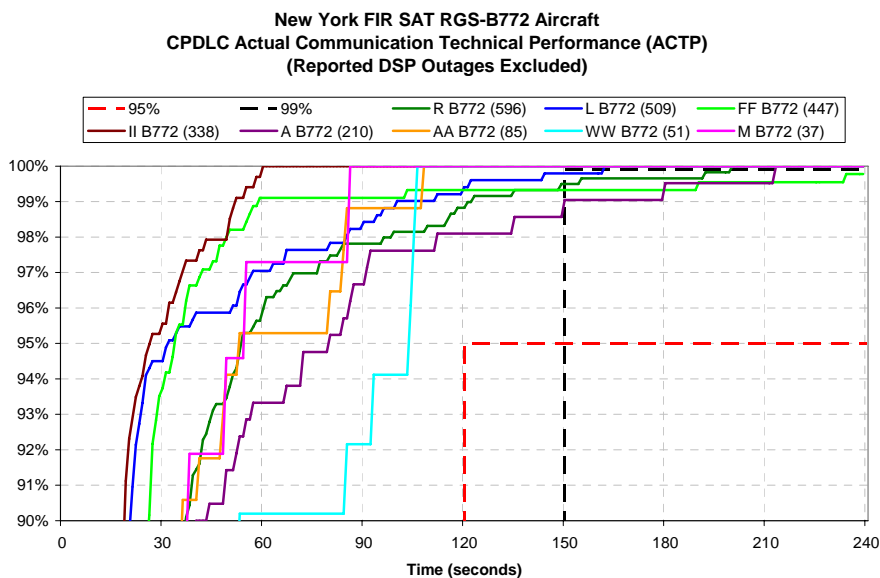


Figure 23. ACTP – New York Oceanic Airspace B772 by Operator

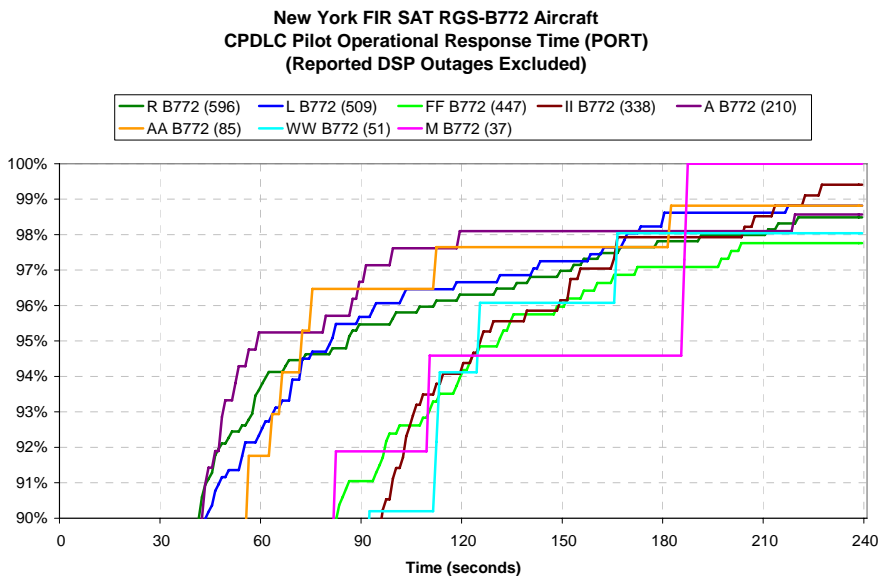


Figure 24. PORT – New York Oceanic Airspace B772 by Operator

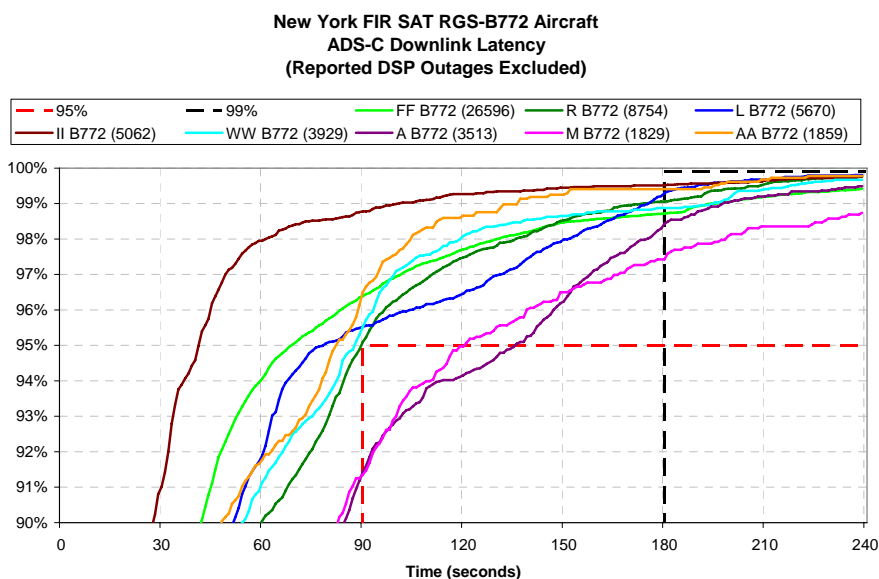


Figure 25. ADS-C Performance – New York Oceanic Airspace B772 by Operator

2.9.1. The 95 percent requirement for ACTP was met by all eight of the B772 operators shown in Figure 23. However, there are two B772 operators that do not meet the 95 percent requirement for ACP. There are two B772 operators that do not meet the 95 percent requirement for ADS-C performance. None of the B772 operators shown in Figures 23 and 25 meet the 99.9 criteria for ACP and ADS-C performance, respectively.

2.9.2. Figures 26 through 29 show the observed ACP, ACTP, PORT and ADS-C performance for B772 aircraft by operator from the Oakland FIR. These observations represent only satellite data link communications (e.g. VHF and HF messages were excluded) for the top 8 B772 operators in the Oakland FIR. Once again, the operator information is desensitized in the figures.

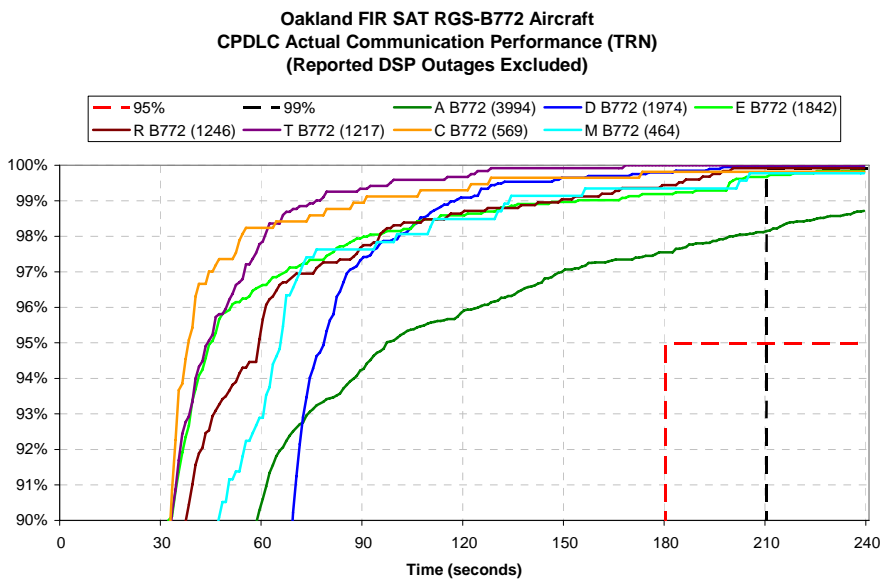


Figure 26. ACP – B772 Operations in Oakland Oceanic Airspace by Operator

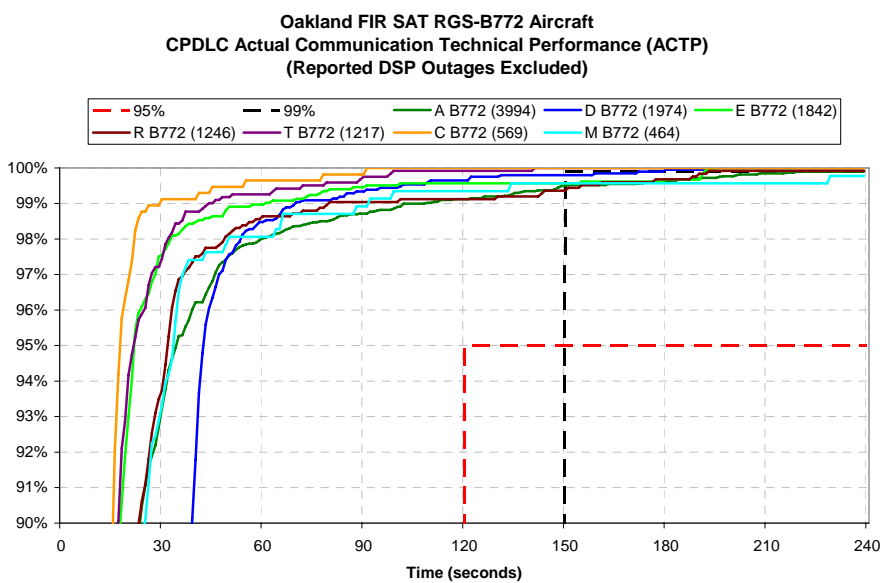


Figure 27. ACTP – B772 Operations in Oakland Oceanic Airspace by Operator

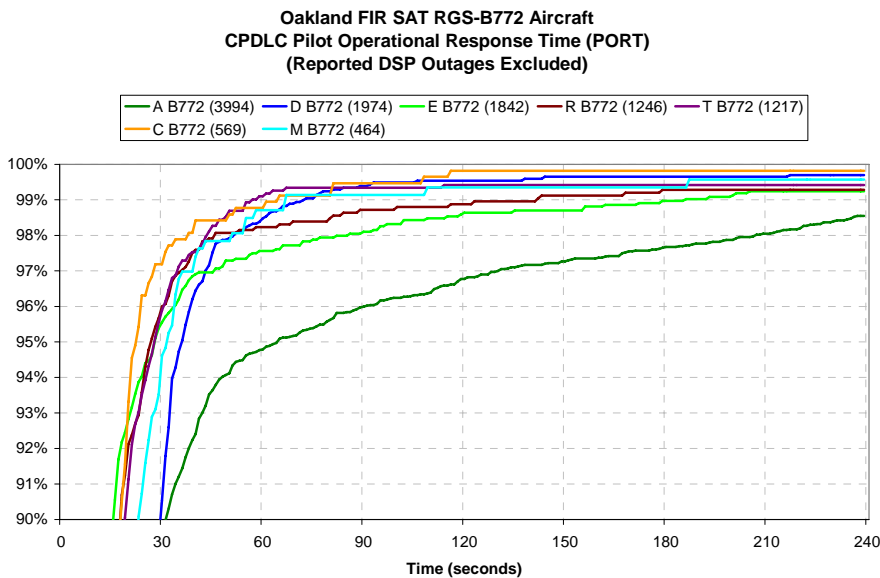


Figure 28. PORT – B772 Operations in Oakland Oceanic Airspace by Operator

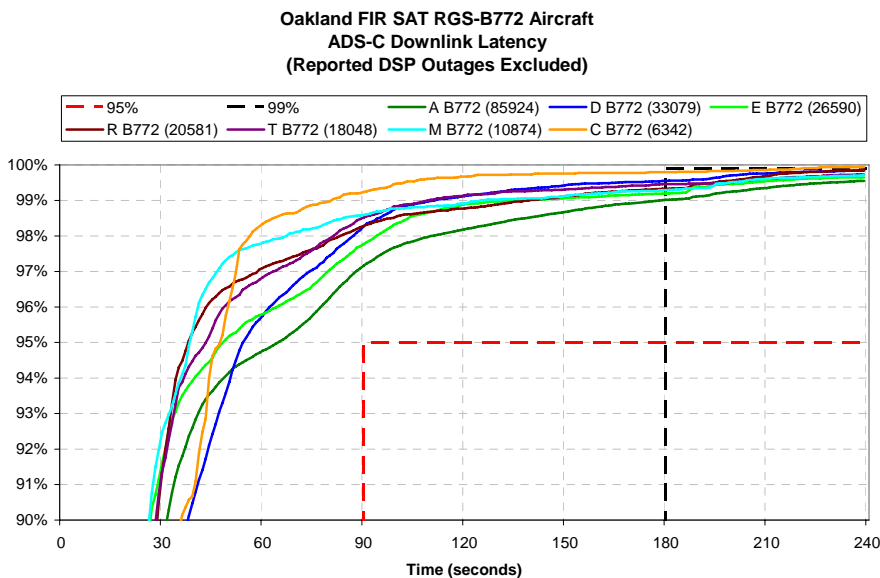


Figure 29. ADS-C Performance – B772 Operations in Oakland Oceanic Airspace by Operator

2.9.3. Overall, the observed ACP, ACTP, PORT and ADS-C performance for the B772 operators in the Oakland FIR exhibit better results than those observed in the New York FIR.

2.9.4. Figures 30 through 33 show the observed ACP, ACTP, PORT and ADS-C performance for A332 aircraft by operator in the New York FIR. These observations represent only satellite data link communications (e.g. VHF and HF messages were excluded). The operator information is desensitized in the figures.

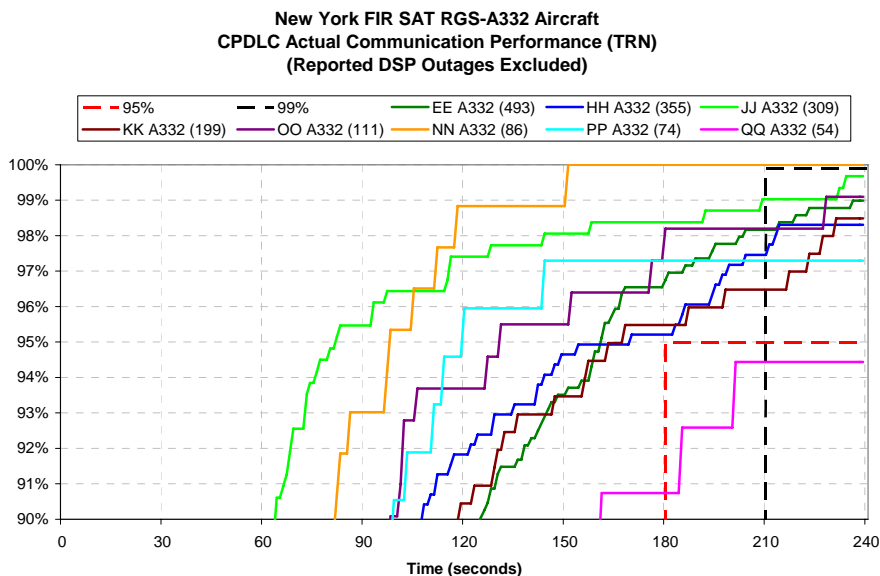


Figure 30. ACP – New York Oceanic Airspace A332 by Operator

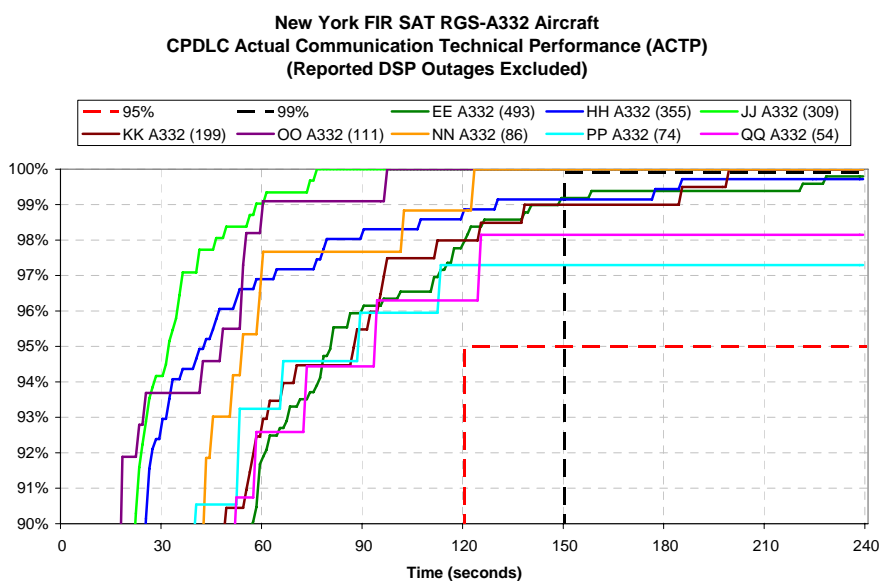


Figure 31. ACTP – New York Oceanic Airspace A332 by Operator

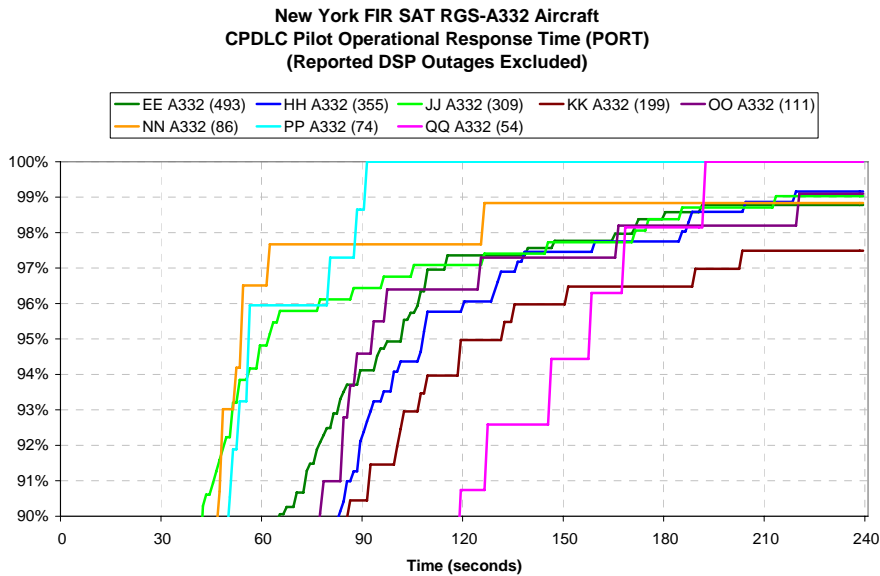


Figure 32. PORT – New York Oceanic Airspace A332 by Operator

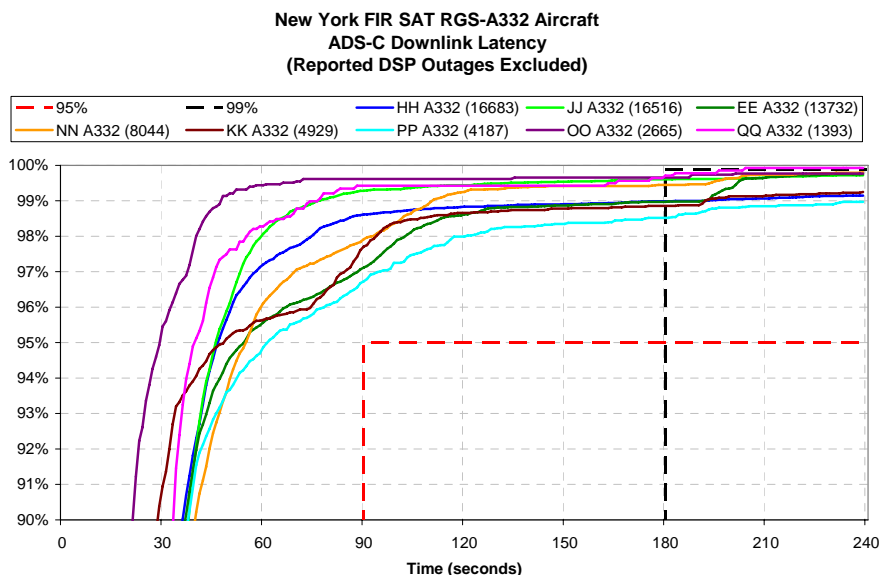


Figure 33. ADS-C Performance – New York Oceanic Airspace A332 by Operator

2.9.5. One A332 operator shown in Figure 30, did not meet 95 percent requirement for ACP. This same operator also shows poor PORT performance levels when compared to the remaining A332 operators.

3. Observed Errors in the Estimated Time of Arrival at Next Position in ADS-C Reports

3.1 Aircraft utilizing ADS-C for position reporting transmit two message types which contain estimates of next position; the Waypoint Change Report (WPC) and Basic Periodic Report (BAS). The reported positions for all aircraft utilizing ADS-C were assembled and organized by message time. The ADS-C messages containing estimates of next position were examined and messages with the current position time exactly equal to the estimate of time over next position were extracted from the data for further analysis.

3.2 Table 1 contains a summary of the initial set of data extracted from the New York and Oakland data sets:

Table 1. Number of ADS-C Reports with Current Position Time Equal to the Estimate of Time Over Next Position

Month	ZOA	ZNY
August 2009	63	24
September 2009	52	91
October 2009	53	103
November 2009	48	89
December 2009	44	84
January 2010	44	89
Totals	304	480

3.3 To further examine the data, the distance between the current position and the estimated next position in each message was calculated as a great circle distance. The assumed average speed of aircraft is typically taken to be 8nm/min. Taking into account the available precision in the time data provided each report and the assumed average aircraft speed of 8nm/minute, the reports containing the error with the estimated distance to the next position of 8 nm or less were removed from the analysis. Table 2 contains the total number of reports remaining after removing position reports in which the estimated distance to the next position estimate was less than 8nm.

Table 2. Number of ADS-C Reports with Current Position Time Equal to the Estimate of Time Over Next Position after Removing Reports with Current Position < 8nm from Next Position

Month	ZOA	ZNY
August 2009	4	10
September 2009	3	81
October 2009	4	98
November 2009	0	78
December 2009	1	77
January 2010	1	77
Totals	13	421

3.4 Table 2 shows a significant drop in the number of errors from Table 1 for ZOA but the same level of reduction was not observed for ZNY. The estimated distances to the next position for the remaining ADS-C reports were further examined. Figures 34 and 35 contain histograms of the estimated great circle distances between the current and next positions provided in these ADS-C reports for Oakland and New York Oceanic Airspace, respectively.

3.5 The horizontal axis in Figures 34 and 35 have the same range although the histogram data from ZOA does not exceed 50nm. However, the histogram data for ZNY exhibits a random pattern across the range of the horizontal axis, the ZNY data range extends from 9nm through 1152nm. The reason for these differences is currently being evaluated, but may be due to the differences in the airspace operations within the New York and Oakland FIRs.

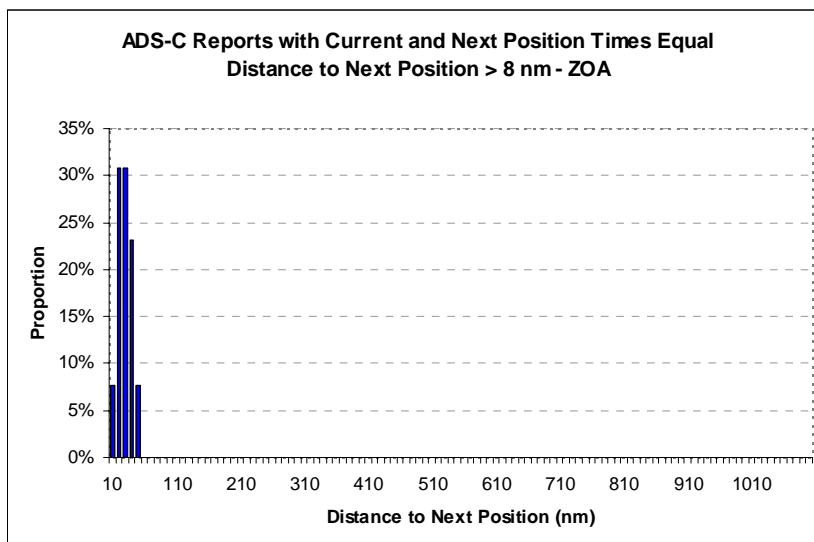


Figure 34. Distance to Next Position Estimated from ADS-C Reports with Equal Current and Next Positions Times – ZOA

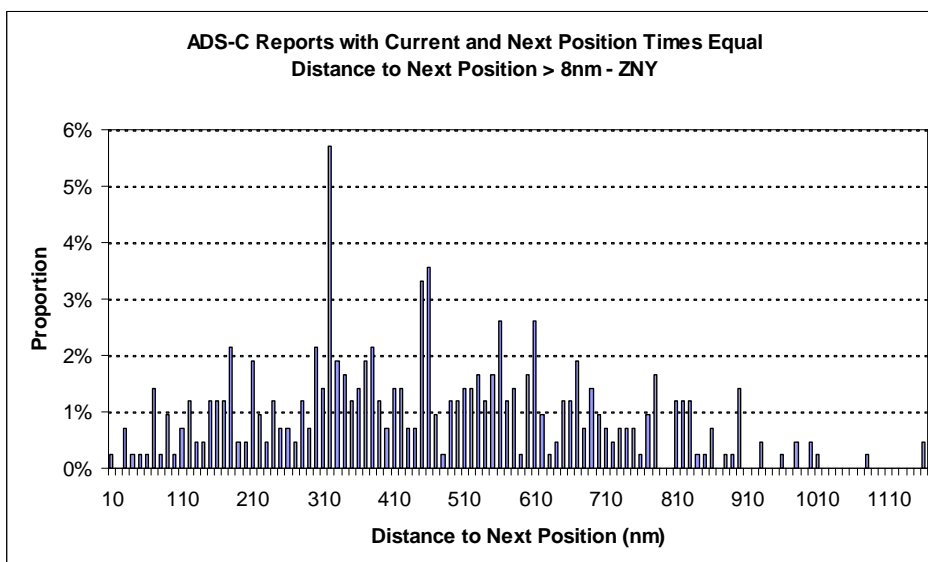


Figure 35. Distance to Next Position Estimated from ADS-C Reports with Equal Current and Next Positions Times – ZNY

3.6 To further study the remaining errors, the aircraft type, aircraft current location, and the current message time were examined.

3.7 All 13 remaining errors observed at ZOA involved B744 aircraft. All 421 remaining errors observed at ZNY involved Airbus aircraft. The A332, A333, A343, and A346 accounted for 21.14, 9.74, 39.43, and 29.69 percent, respectively, of the remaining errors.

3.8 The current locations of the aircraft obtained from each of these remaining errors are shown in Figures 36 and 37.

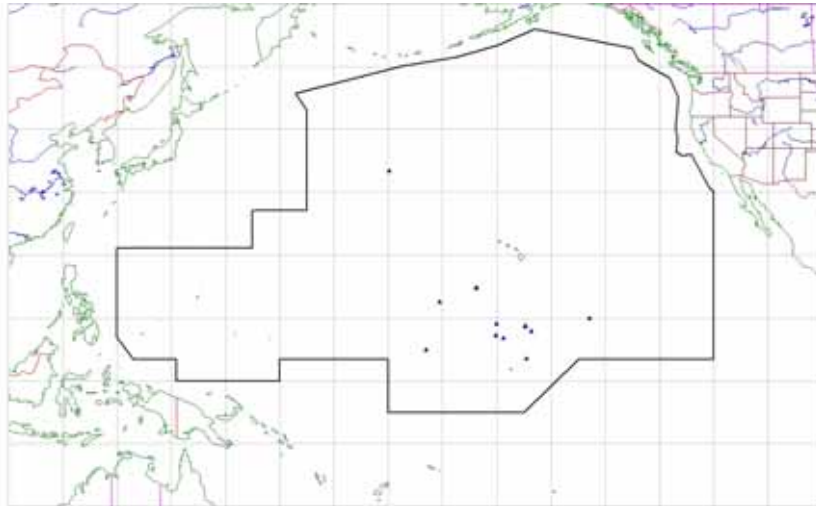


Figure 36. Location of ADS-C Position Reports with Same Current and Next Position Time in ZOA

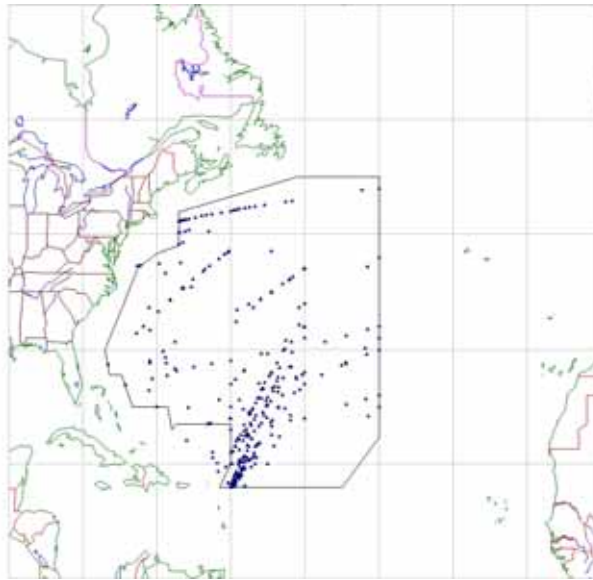


Figure 37. Location of ADS-C Position Reports with Same Current and Next Position Time in ZNY

3.9 Lastly, the current position was examined for each of the remaining reports in Table 2. Figures 38 and 39 present the observed current position time.

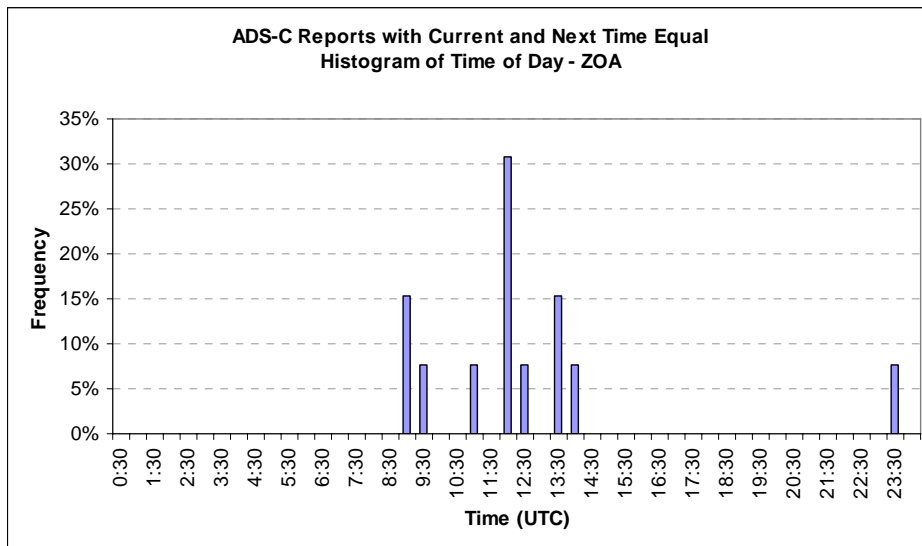


Figure 38. Current Time ADS-C Position Reports with Same Current and Next Position Time in ZOA

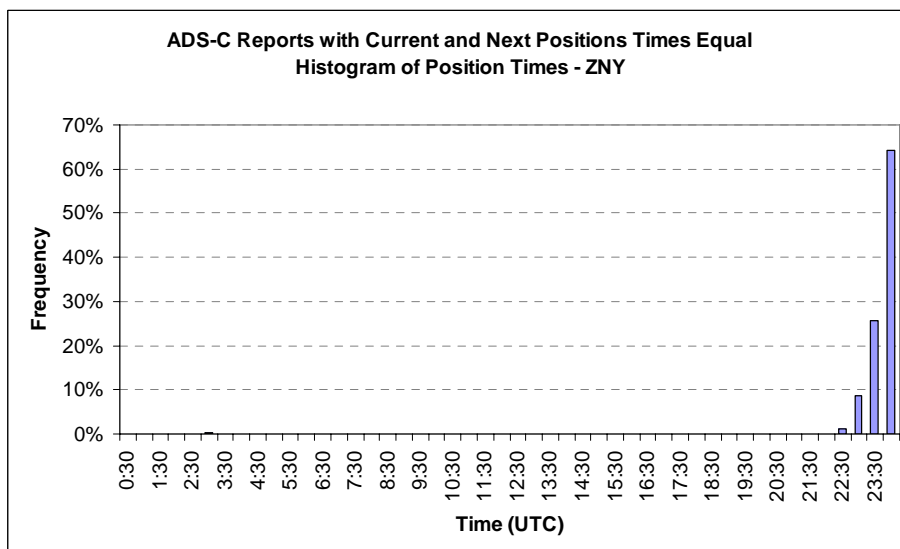


Figure 39. Current Time ADS-C Position Reports with Same Current and Next Position Time in ZNY

3.10 The ADS-C reports received at ZNY with the current position time and estimated time of arrival at next position equal were all provided by Airbus aircraft. The data do not show any trends related to the current position of the aircraft. However, the data show a pattern associated with the time of the current position shown in Figure 37.

3.11 The FAA has notified Airbus of the problem with ADS-C position reporting. Airbus has responded and indicated that the problem has been identified and plans a fix for 2012.

4. Action

4.1 The meeting is invited to note the information contained within this paper.

-END-