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Lima, Peru, from September 11 to 15, 2023

Agenda Item 5: Other matters

TECHNICAL ANALYSIS REGARDING THE PERFORMANCE OF THE DATA LINK CAPACITY DURING THE PERIOD IN WHICH THE ITCZ (INTERTROPICAL CONVERGENCE ZONE) IS ACTIVE IN THE FIR-AO AREA

(Submitted by CARSAMMA)

EXECUTIVE SUMMARY	
This informative note presents the analysis carried out in relation to the data link capacity, mainly in relation to the Figure of Merit (FOM) and CPDLC, with a view to the PBCS operation, when the Intertropical Convergence Zone is active in the FIR-AO area.	
Objectives Strategic:	• Air navigation capacity and efficiency
References:	▪ GOLD - *Global Operational Datalink Document - Second Edition* 2013; ▪ ACARS 620-9 – *Datalink Ground System Standard And Interface Specification*; ▪ RTCA DO 219 – *Minimum Operational Performance Standards for ATC Two-Way Data Link Communications;* ▪ DOC 9869 – *Performance-based Communication and Surveillance (PBCS) Manual;* ▪ Operator Manual Station CTR/ASS – ATECH Negócios em Tecnologias S/A; ▪ Climatological Study nº 001/SCO/2023; and ▪ Technical Opinion nº637199/DT-TIOP/2022.

1. Introduction

1.1. This information paper presents the analysis carried out regarding the data link capacity, related to the Figure of Merit (FOM) and CPDLC, with a view to the PBCS operation, when the Intertropical Convergence Zone is active in the FIR-AO area.

The data collected allowed the following analyses to be carried out:

- Latency analysis of surveillance data;
- Analysis of the response time of communications; and
- Navigation accuracy of aircraft operating data link in FIR-AO.

1.2. The objective was to observe whether the communication performance of the data link meets the communication and surveillance requirements RCP240 and RSP180 in the period when there is greater meteorological activity in the FIR-AO, which can impact the performance of the satellite link. For the use of the Figure of Merit as a navigation parameter, the provisions of GOLD, DOC 9869 and the STVD SAGITTARIUS operation manual were observed.

1.3. To perform the analyses, statistical methods of frequency distribution were applied in order to obtain the behavior of latency over time.

1.4. In addition to these factors, compliance with the follow-up criteria was observed, according to GOLD, which defines two parameters described below:

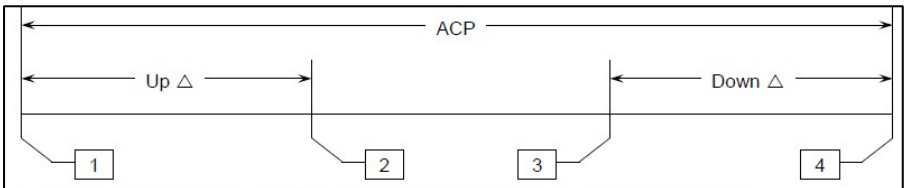
• ***99.9% criterion:*** the 99.9% criterion defines the Expiry Time (ET) for communication transactions and the Expiry Time (OT) for surveillance transactions, after which the initiator is required to return to an alternative procedure. When using data binding to provide reduced separations, the RCP240 **ET** and the RSP180 **OT** are the times after which, if an intervention transaction is not completed, **CPDLC** or a position report is not received **ADS-C**, the controller must revert to the separation procedure alternative as defined in the separation specification. If monthly monitoring indicates that a specific fleet does not meet the criteria, a local safety assessment should be conducted by the **ANSP** to assess whether the reduced separation standard can still be applied.

• **95% criterion:** The 95% criterion defines the acceptable nominal time for normal operations of **CPDLC and ADS-C**. If monthly monitoring shows that measured performance is consistently below the 95% criterion, retirement of data link services to the fleet may be considered. Experience has shown that observed fleet performance below the specified RCP240/RSP180 criteria of 95% will usually be accompanied by complaints from the controller about the unacceptable performance of that fleet.

• The **CPR** (Required Performance in Communications) is the composition of the technical time of transmission of the message, reaction time and technical time of receipt of the message. The GOLD establishes the following relationship:

- ACTP: Total technical time of transmission and reception of messages;
- PORT: ATCO and/or Pilot Operating Time;
- ACP: Total elapsed time since the message is sent until the response is received.

1.5. To calculate these parameters, GOLD suggests the following method:



1. Uplink Sent. This is the date/time that the CPDLC clearance was sent to the aircraft.
2. MAS Received. This is the date/time that the MAS for the CPDLC clearance was received.
3. WILCO Sent. This is the date/time that the WILCO reply is transmitted.
4. WILCO Received. This is the date/time that the WILCO reply for the CPDLC clearance was received.

The measurements (in seconds) are calculated as follows:

$$ACP = (WILCO\_Received) - (Uplink\_Sent) \rightarrow TRN$$

$$ACTP \cong \left(\left(\frac{Up\Delta}{2}\right) + (Down\Delta)\right) \rightarrow RCTP$$

$$PORT \cong ACP - ACTP \rightarrow Responder$$

Figure 1 Calculation method for ACP, PORT and PTCA

1.6. The values of the parameters foreseen in the GOLD are:

RCP communication transaction time and continuity criteria			
Specification: RCP 240/D	**Application: CPDLC**		**Component: ANSP**
Transaction Time Parameter	**ET (sec) C = 99.9%**	**TT (sec) C = 95%**	**Compliance Means**
Transaction Time Value	240	210	Analysis, CSP contract/service agreement. See also paragraph B.3.1.3.
RCP Time Allocations			
Initiator	30	30	Analysis, simulations, safety and human factors assessments
TRN	210	180	Monitored, CSP contract/service agreement. See also paragraph B.3.1.3.
TRN Time Allocations			
Responder	60	60	Initially, by analysis, simulations, safety human factors assessments Post-implementation, monitored, estimated
RCTP	150	120	Monitored, estimated, CSP contract/service agreement. See also paragraph B.3.1.3.
RCTP Time Allocation			
$RCTP_{ATSU}$	15	10	Pre-implementation demonstration

Table 1 GOLD parameters for RPC 240

2. Analysis

Data Analysis

2.1. The data obtained were analyzed by the team of the Operational Informatics Section of CINDACTA III, as follows:

- **Ascent Latency Analysis (ACTP_S):** Analyzes the time between the transmission of the data packet by the ATCO and its reception by the aircraft;

- **Descent Latency Analysis (ACTP_D):** Analyze the time between the transmission of the data packet by the aircraft and its reception by the ATCO;

- **Response time (PORT):** Consult the response time of the ATCO or PILOT;

- **Total Communication Time (PCA) Analysis:** Analyze the total time elapsed between transmission, processing, treatment and response;

- **ADS-C Surveillance Data Latency (ASP):** Analyze the time between the issuance of the position report and the reception by the ATCO;

- **Navigation Accuracy (FOM):** Quantify the aircraft that flew over the FIR-AO in relation to the Figure of Merit (FOM) of the ADS communication, mainly in relation to the FOM 7 which has the highest navigation accuracy (0.05Nm).

Network connections

2.2. CINDACTA III has a data link connection with the company SITA with a view to the operation of ADS-C and CPDLC in the ACC-AO, having two different links: internet and intraer. In addition, two redundant SITA processors are used, one installed in Montreal, Canada and the other at Galeão Airport in Rio de Janeiro.

Meteorological Study

2.3. The Integrated Center for Aeronautical Meteorology (CIMAER) carried out, at the request of CINDACTA III, a Meteorological study on the incidence of the Intertropical Convergence Zone (ITCZ) in the FIR-AO area. The objective of the study is to understand that this meteorological phenomenon occurs during the period of greatest intensity and approach to the continent, which is characterized by the meeting of the trade winds, coming from the northern and southern hemispheres, which generates instability, strong air currents, intense formation of convective clouds accompanied by liquid or solid precipitation, electric shocks, intense winds, turbulence and others.

2.4. As reported by CIMAER, the ITCZ migrates in an annual cycle around the geographical equator, following the climatic seasons due to the variation of the average temperature in the hemispheres.

2.5. Based on the meteorological study, it seems that the months between March and May present the ZCIT closest to the continent, directly affecting the FIR-AO in the EUROSAM corridor. The figures below, taken from that document, show this condition.

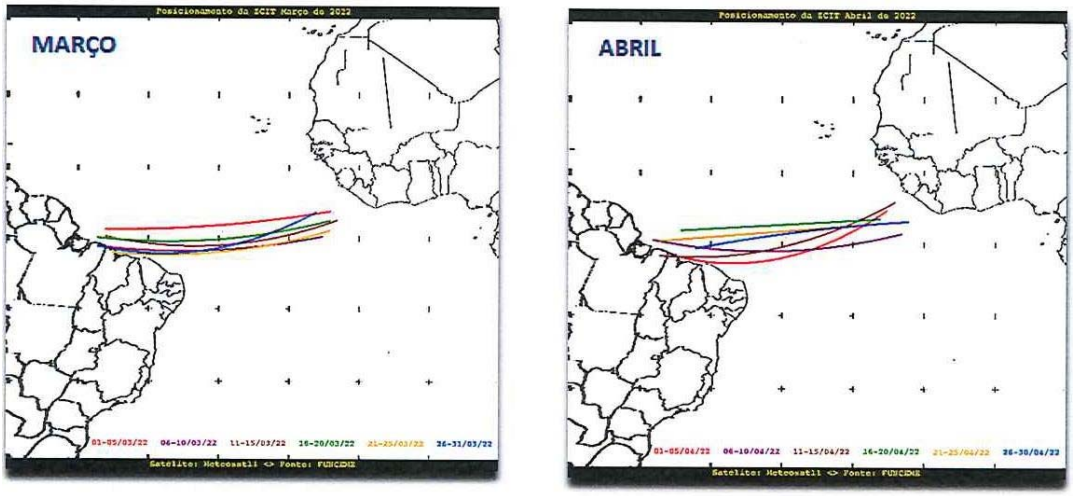


Figure 2 ITCZ positioning in March and April.

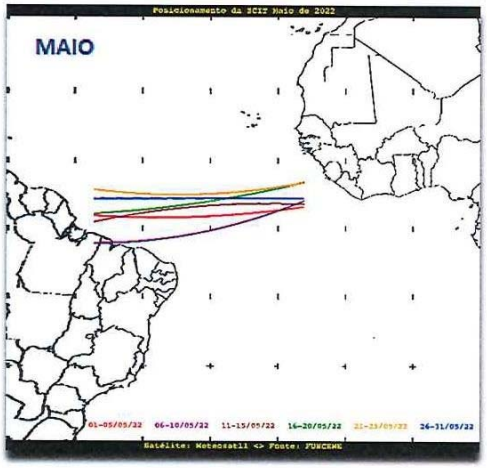


Figure 3 ITCZ positioning in May.

2.6. Other analyses related to the behavior of the data link in the FIR-AO focused on the period from March to May 2022, according to data from the study presented by CIMAER. This data link performance analysis during the ITCZ was necessary, as electromagnetic waves from satellite communication, in the band that are used by the SITA service, could be impacted by the intense formation of convective clouds and electrical discharges.

Surveillance Data Latency Analysis

2.7. One of the main points to study for separation reduction is latency. This parameter aims to obtain the average time between the transmission of the data packet and its reception by the receiver. The lower this value, the better the communication regarding safety and air traffic control performance. Several factors influence this parameter:

- Retransmissions caused by communication failures;
- Performance of aircraft avionics;
- Performance of terrestrial links;
- Data link provider performance.

2.8. For the selected period, i.e. between March and May 2022, 90405 ADS-C data were processed. The graphs below show the latency frequency distribution and ASP.

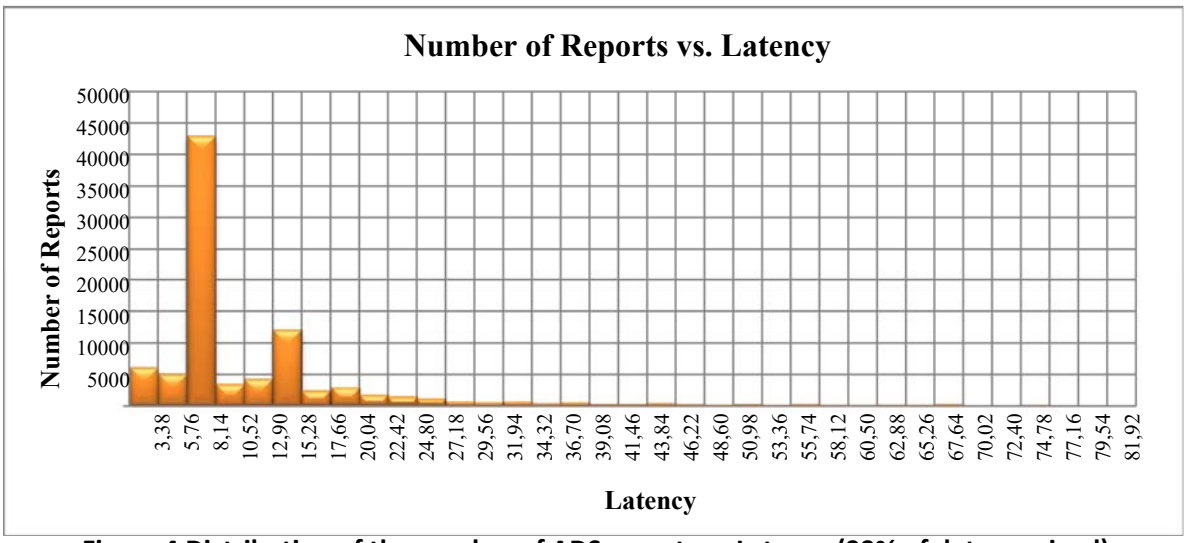


Figure 4 Distribution of the number of ADS reports vs Latency (99% of data received)

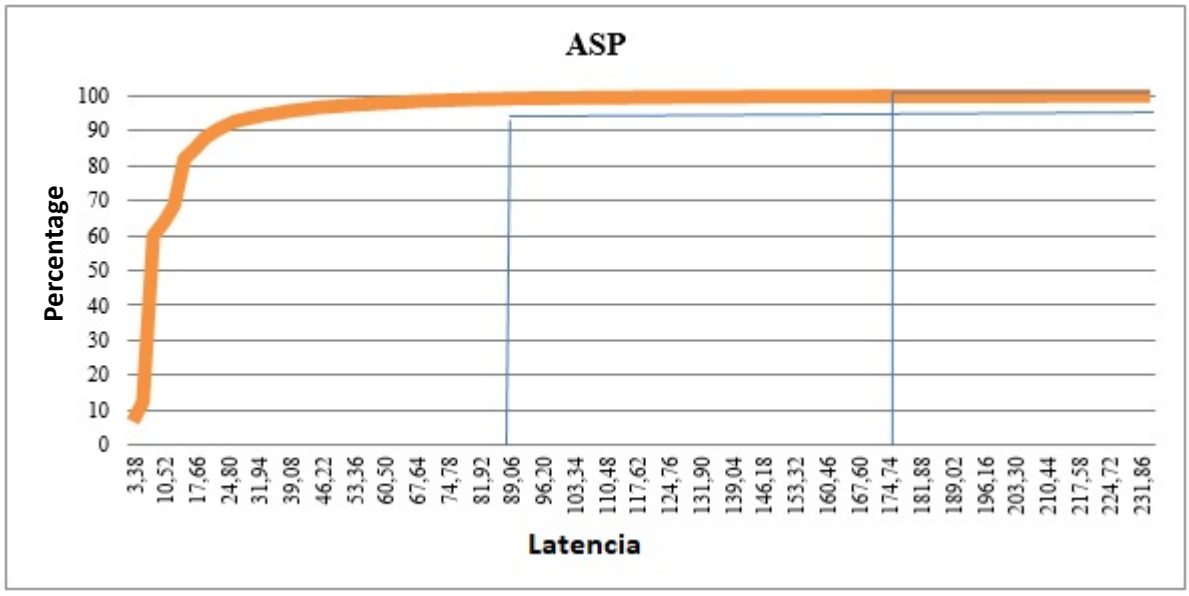


Figure 5 ASP chart for the period

2.9. As described in GOLD, ADS-C data must have latency of up to 90 s 95% of the time and 180 s 99.9%. From the ASP graph in Figure 5, it can be seen that the result obtained in the FIR-AO meets the RSP180 performance requirement.

Communication Response Time Analysis

2.10. A complete analysis of all communication parameters provided for in the CPR was performed. As the data was extracted from flights already performed, we call the result ACP (Actual Communication Performance). This more complete analysis was necessary according to the conclusion of the previous study published in Report No. 637199/DT-TIOP/2022, of November 21, 2022.

2.11. For the evaluated period, 16519 messages were processed in the FIR-AO. As a result, the following behavior expressed in frequency distribution was obtained:

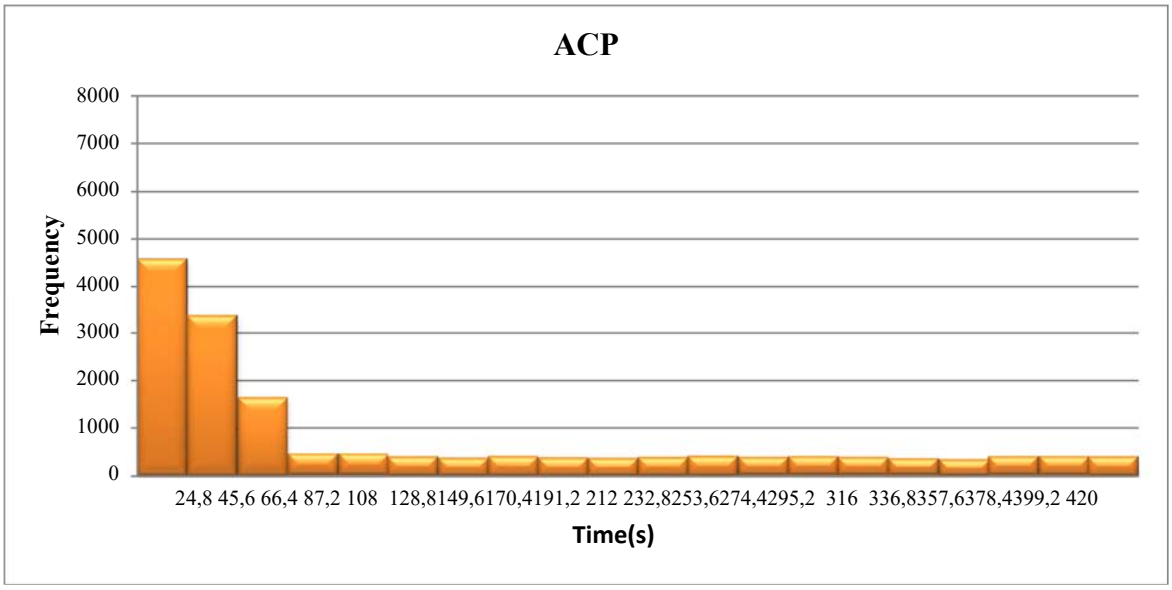


Figure 6 Distribution of the number of CPDLC messages vs Latency (99% of data received)

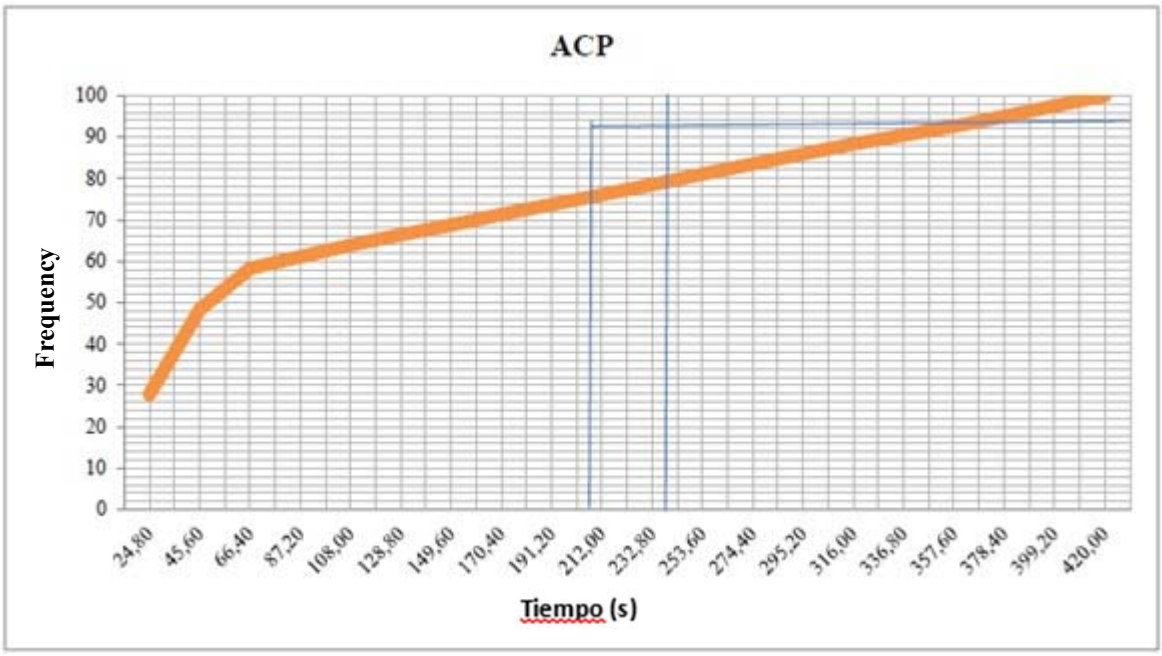
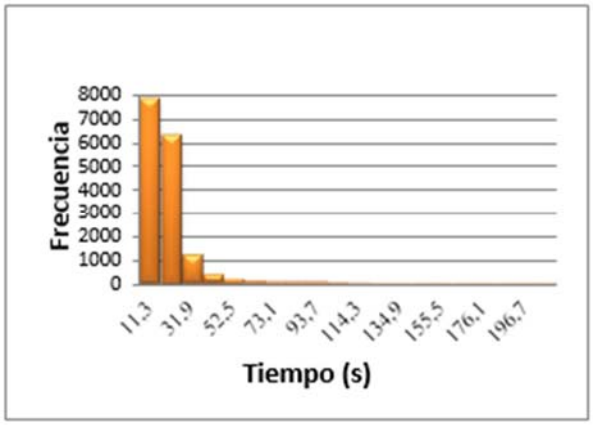


Figure 7 ACP chart for the period

2.12. According to the constant parameter of Table 1, it can be seen in Figure 7 that the PCA found for the analyzed period does not meet the criteria of 95% and 99.9% continuity. This behavior was also seen in the previous study that analyzed the periods of August and September 2022, that is, without the impact of the ITCZ.

2.13. To detect which parameter is affecting performance, ACTP and PORT were observed.

PTCA **PORT**



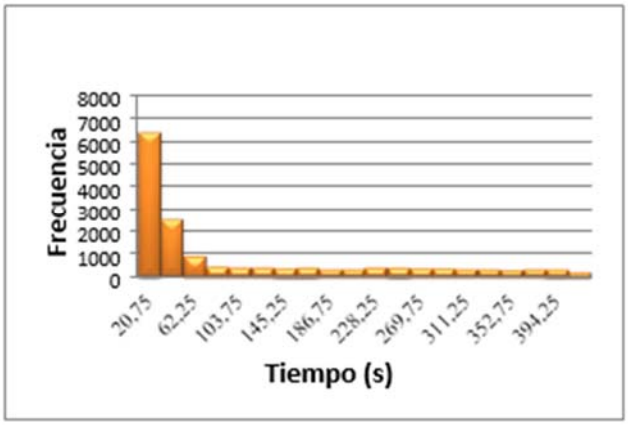


Figure 8 ACTP frequency distribution Figure 9 PORT frequency distribution

2.14. We can see in Table 1 that the predicted time of PORT, also called TRN, is estimated at 60 s. From the graph in Figure 9, together with Table 2, it can be seen that only 60% of the messages were answered within the 60s.

Table 2 – Absolute PORT Time Distribution

PORT		
Cutting Time	***Absolute***	***Percentage***
20,75	***rubbing***	39,19728797
41,50	6475,00	54,75513046
62,25	9045,00	***60,24577759***
83,00	***9952,00***	63,00018161
103,75	10407,00	65,60929838
124,50	10838,00	68,22446879
145,25	11270,00	70,60354743
166,00	11663,00	73,12791331
186,75	12080,00	75,37381197
207,50	12451,00	77,66813972
228,25	12830,00	80,28936376
249,00	13263,00	82,77740783
269,75	13674,00	85,13227193
290,50	14063,00	87,45081421
311,25	14446,00	89,73908832
332,00	14824,00	91,97287971
352,75	15193,00	94,01900841
373,50	15531,00	96,30728252
394,25	15909,00	98,55923482
415,00	16281,00	100

2.15. The ACTP parameter (RCTP) is 120 s at 95 % and 150 s at 99.9 %. In the data collected, 99.7% of the messages had PTCA below 120 s and 99.9% were below 150 s, as shown in Table 3 and Figure 8.

Table 3 - Absolute Time Distribution of PTCA

ACTP		
Cutting Time	***Rub. Absolute***	***Percentage***
11,30	7908,00	47,87214722
21,60	14345,00	86,83939706
31,90	15561,00	94,20061747
42,20	15952,00	96,56758884
52,50	16116,00	97,56038501
62,80	16222,00	98,20207034
73,10	16286,00	98,589503
83,40	16346,00	98,95272111
93,70	16406,00	99,31593922
104,00	16442,00	99,53387009
114,30	16466,00	99,67915733
124,60	***16476,00***	***99,73969369***
134,90	16482,00	99,7760155
145,20	16491,00	99,83049821
155,50	***16504,00***	***99,90919547***
165,80	16506,00	99,92130274
176,10	16509,00	99,93946365
186,40	16512,00	99,95762455
196,70	16516,00	99,98183909
207,00	16519,00	100

Aircraft Navigation Accuracy Operating Data Link in the FIR-AO in the Active Period of the ZITC

2.16. The ADS-C protocol has a parameter called Merit Figure, which allows to statistically determine the reliability and accuracy of the aircraft's navigation data. Eight (8) levels are possible, as shown in the following table:

FOM	Position Accuracy	Feedback
0	Total loss of navigation capacity	There is no possibility to determine the position within 30Nm and it is considered loss of navigation capability
1	< 30 nm	Consistent with inertial navigation throughout the flight without updates.
2	< 15 nm	Consistent with inertial navigation throughout the flight with interspace without upgrades.
3	< 8 nm	Consistent with inertial navigation throughout the flight with little space without updates and around 50Nm from a VOR.
4	< 4 nm	Consistent with VOR accuracy at 50 Nm or less and with GPS.
5	< 1 nm	According to RHO-RHO DME, RNAV applications use multiple position updates via DME or GPS.
6	< 0.25 nm	Consistent with RNAV using GPS.

7	< 0.05 nm	Consistent with higher GPS accuracy.

2.17. The Figure of Merit was created to increase flight controller awareness of the reliability of aircraft navigation data, particularly in regions where there is no coverage from other sensors that could improve the accuracy of position information. For an RNP10 aircraft, the FOM must be level 3 or higher. For RNP 4, the FOM must be 4 or greater.

For the period under analysis, the behavior described in Figure 10 and Table 4 was obtained.

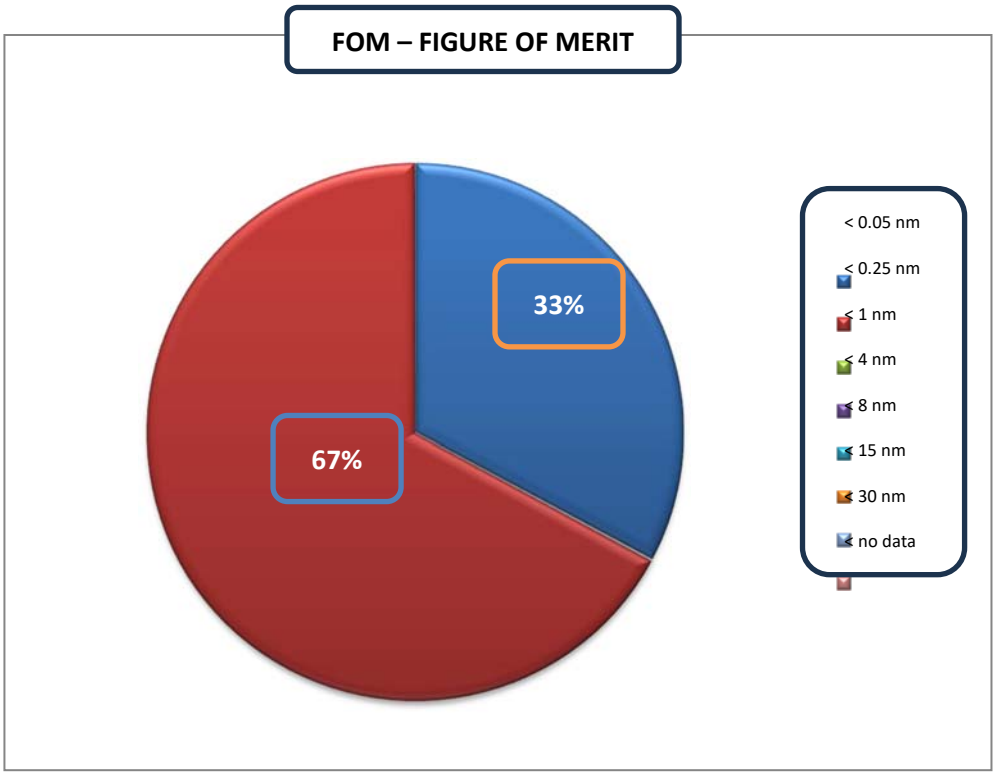


Figure 10 - Distribution of FOM values

Table 4 – FOM values observed in the FIR-AO

FOM		***Quantity***
7	< 0.05 nm	29681
6	< 0.25 nm	60697
5	< 1 nm	17
4	< 4 nm	0
3	< 8 nm	0
2	< 15 nm	0
1	< 30 nm	0
0	No Data	10

2.18. As noted above, the majority of ADS-C reports had FOM6 and later FOM7 navigation accuracy information. These data are fully compatible with the analysis carried out in Technical Opinion No. 637199/DT-TIOP/2022.

3. Conclusion

3.1. As it can be observed, based on the analyses carried out, that the behavior presented by the data link communication in the FIR-AO, during the period of active ITCZ, remained constant and in the same parameters observed in the study carried out at the end of 2022 It is assumed that the ITCZ does not impact the performance and results with a view to the operationalization of the PBCS in the oceanic region. However, further operational studies on the PORT (TRN) are needed, as this action does not comply with GOLD and DOC 10063.

4. Suggested actions

4.1 The meeting is invited to take note of the information contained in this information paper.

— END —