International Civil Aviation Organization

ELEVENTH MEETING OF THE SURVEILLANCE IMPLEMENTATION COORDINATION GROUP (SURICG/11)

Bangkok, Thailand, 25 – 27 March 2026

Agenda Item 7: Report on surveillance ground system and avionics performance monitoring and improvement in compliance

Status Update on ADS-B Performance Monitor Under Development at ENRI

(Presented by Junichi Honda/Electronic Navigation Research institute)

SUMMARY

This paper provides a status update on the ADS-B performance monitor under development at ENRI, which was presented at ASWG/23 in March 2026.

1. INTRODUCTION

1.1 Japan Civil Aviation Bureau (JCAB) is planning to use ADS-B for air traffic control. Therefore, the evaluation system for ADS-B performance is necessary to ensure safe aircraft operations.

1.2 Electronic Navigation Research Institute (ENRI) developed an algorithm for the analysis of ADS-B message. We measured the adoption rate of ADS-B and statistically analysed its performance quality in the airspace and on the airport surface in Japan. The results were reported in SP-ASWG (SP-ASWG17-IP/05, SP5-ASWG18-IP/05, SP-ASWG19-IP/07R1, SP-ASWG20-IP/08). The results are similar to those reported by the FAA. However, the performance observed on the ground was degraded compared with that observed in airborne measurements. These results were estimated to include engine start timing and aircraft in the hanger.

1.3 In 2025, ENRI has developed a performance monitor to evaluate ADS-B performance based on the our previously developed algorithm. Since then, the monitor has been continuously enhanced to improve its functionality. The monitor can be used to assess the current ADS-B situation in Japanese air space and to identify aircraft that does not meet the surveillance requirement. After the overview was presented at SURICG/10, the software functionality was extended. This information paper (IP) presents the status update on the ADS-B performance monitor at ENRI, which was presented at ASWG/23 in March 2026 (ASWG23-IP/04).

2. DISCUSSION

2.1 An ADS-B message includes not only its own position (latitude, longitude, and altitude) but also indices of positional performance (NIC and NACp) computed using data from the onboard GNSS receiver. In addition, operational information on avionics installation issues (NACv, SDA, SIL, etc.) is provided. Even if the position computation is correct, ADS-B sometimes provides erroneous information due to the installation-related factors. Therefore, evaluating the types of ADS-B information is necessary to determine overall ADS-B performance. Statistical analysis is suitable for this purpose, enabling the assessment of ADS-B performance quality.

2.2 According to 14 CFR 91.227, the requirements for ADS-B Out performance are defined as follows:

- Navigation Accuracy Category; position (NACp) must be less than 0.05 NM, resulting in NACp≧8.
- Navigation Accuracy Category; velocity (NACv) must be less than 10 m/s, resulting in NACv≧1.
- Navigation Integrity Category (NIC) must be less than 0.2 NM, resulting in NIC≧7.
- System Design Assurance (SDA) must be less than or equal to 10-5 per flight hour, resulting in SDA≧2.
- Source Integrity Level (SIL) must be less than or equal to 10-7 per flight hour, resulting in SIL=3.

Operational availability is also defined as the percentage of time that a system is available at the expected level of performance (SP-ASWG17-IP01). We selected an operational availability requirement of greater than or equal to 99.9%.

2.3 Figure 1 shows a block diagram of ADS-B processing. Our software operates in two formats: using Mode S messages or using CAT21 (ADS-B ASTERIX) format processed by the operational systems. When using Mode S format observed ADS-B receiver or MLAT receivers, the processing is performed according to the developed algorithm as follows:

1) Decoding Mode S messages and extracting DF=17 (and 18), allowing the estimation of ADS-B adoption rate in Japan.
2) Classifying aircraft in each ADS-B version using FTC=31 and the datasheet of each ADS-B version (prepared aircraft lists).
3) Creating a dataset of positional data linked with various datasets (NIC, NACp, NACv, SDA, SIL, etc.) as presented in the previous section. Each position data is always associated with the aforementioned datasets.
4) Statistically analysis is performed using the dataset created in the previous step.

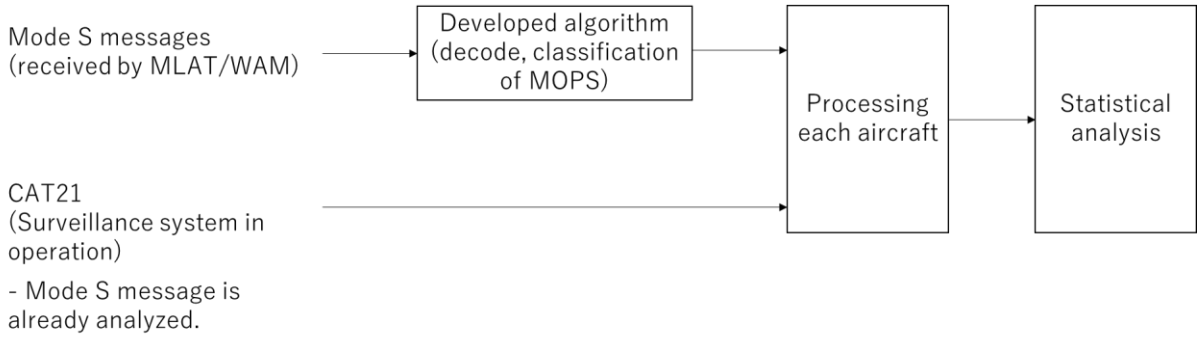


Figure 1 Block diagram of ADS-B processing

The reasons for using two formats are as follows. The first allows flexible customization of the analytical procedure for ADS-B messages, while the second verifies whether the operational surveillance system transmits accurate data.

2.4 We have developed software for evaluating the quality of ADS-B performance. Some screenshots of the software are shown below. During the research phase, the software was implemented in MATLAB. The results were analysed using CAT21 data obtained from the operational system.

2.5 Figure 2 shows the main window for selecting a file format. This software can read two types of files: CAT21 and Mode S messages. The software also allows users to reload previously analysed files. Figure 3 shows the window after reading the input files, where some analysed results can be selected. In this software, the following outputs are generated, as shown in Figure 4 and subsequent figures: summary of the analysis, adoption rate of each ADS-B versions, an aircraft list, trajectories, a failure aircraft list, an excluded aircraft list, NIC quality, and a statistical analysis of NIC and NACp.

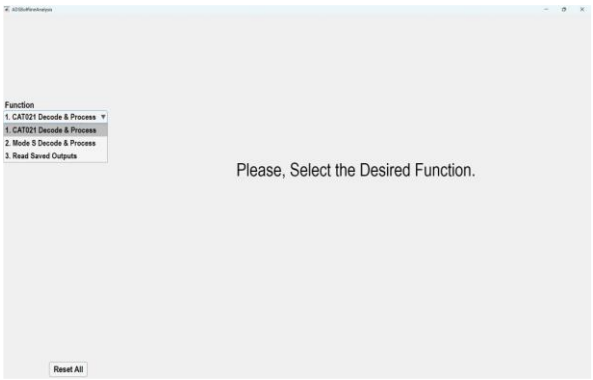


Figure 2 File selection

Figure 3 Result selection

2.6 Figure 4 show a summary of the results, in which various values are presented as follows: the total number of messages, the number of aircraft, the number of each ADS-B version, etc. Figure 5 shows the adaptation rate of ADS-B versions. In this IP, data collected over one month on the main island of Japan were used. Approximately ninety-one percent of the aircraft were identified as Version 2.

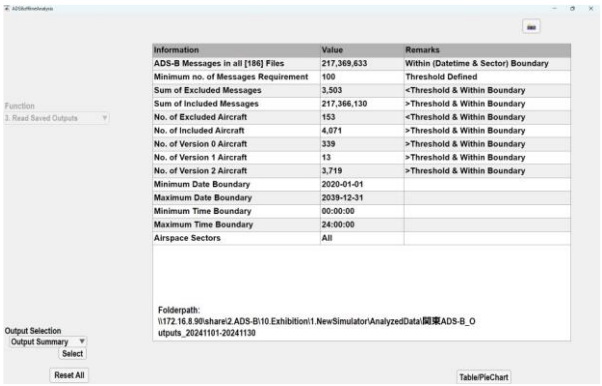


Figure 4 Summary of the analysis

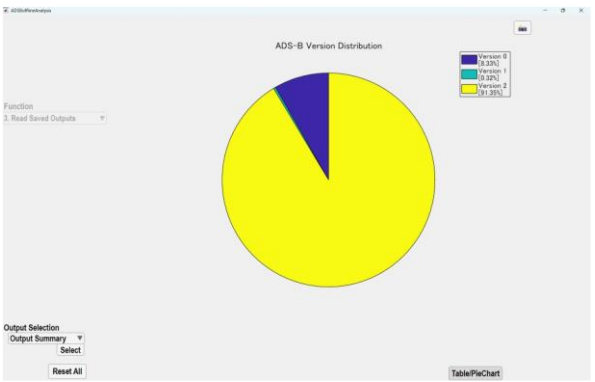


Figure 5 Adoption rate of ADS-B

2.7 Figures 6 and 7 show the trajectories. Figure 6 presents the trajectories by ADS-B version, and Figure 7 presents the trajectories by altitude.

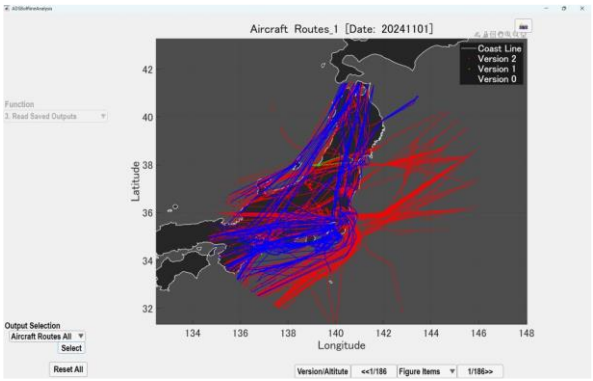


Figure 6 Trajectories by ADS-B versions

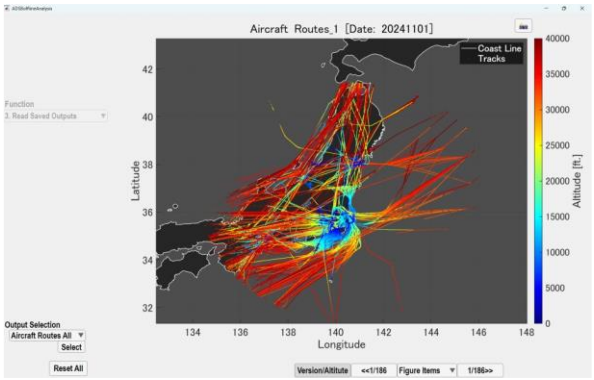


Figure 7 Trajectories by altitude

2.8 Figures 8 shows a list of aircraft, omitting those not included in the analysis. Figure 9 shows the trajectories of a single aircraft by altitude. Trajectories can be generated not only based on altitude but also in conjunction with NIC, NACp, NACv, SIL and SDA.

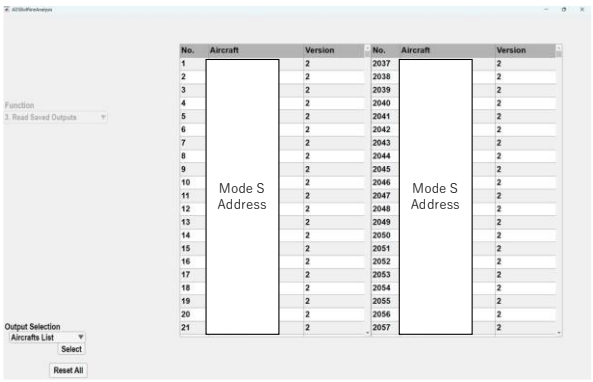


Figure 8 Aircraft list

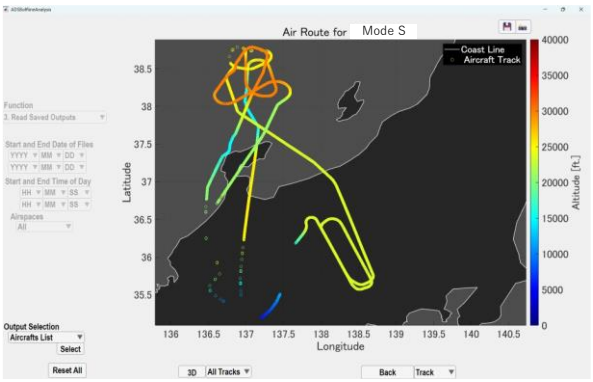


Figure 9 Trajectories of a single aircraft

2.9 Figure 10 shows a list of failed aircraft that do not meet the surveillance requirements, with the cause of each failure indicated in the right column. Figure 11 shows NIC values along the trajectories of a failed aircraft, which consistently transmitted NIC values of zero. Figures 12 to 15 illustrate trajectories along with additional parameters, including NACp, NACv, SIL and SDA. NACp and NACv values were consistently transmitted as zero, similar to NIC. The SIL and SDA values were generally satisfactory.

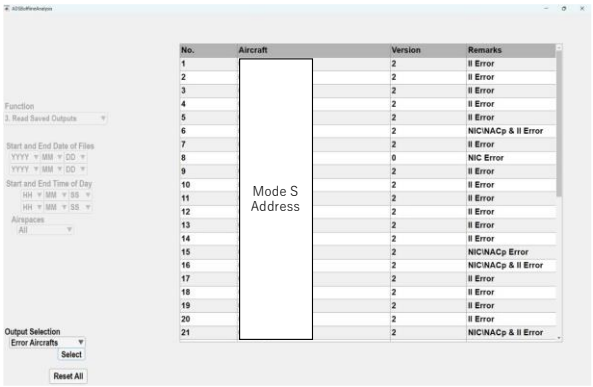


Figure 10 Failure aircraft list

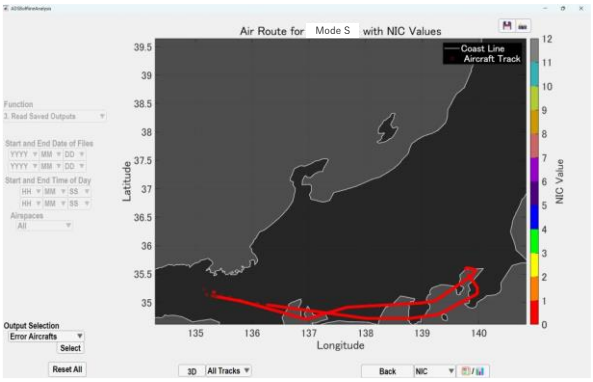


Figure 11 NIC values along the trajectories of a failure aircraft

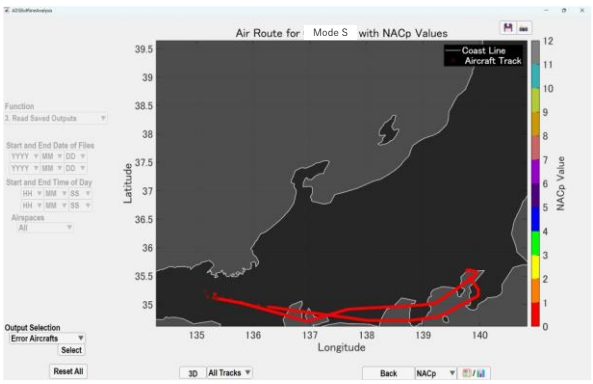


Figure 12 NACp values along the trajectories of a failure aircraft

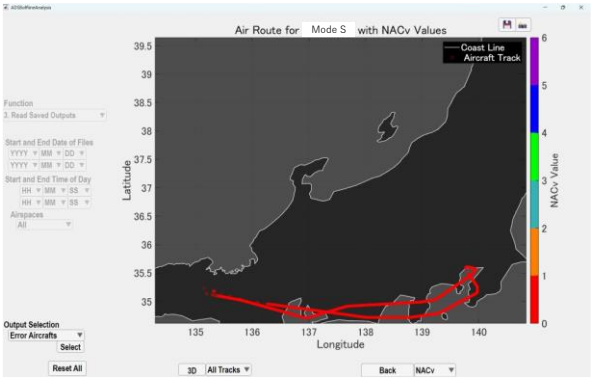


Figure 13 NACv values along the trajectories of a failure aircraft

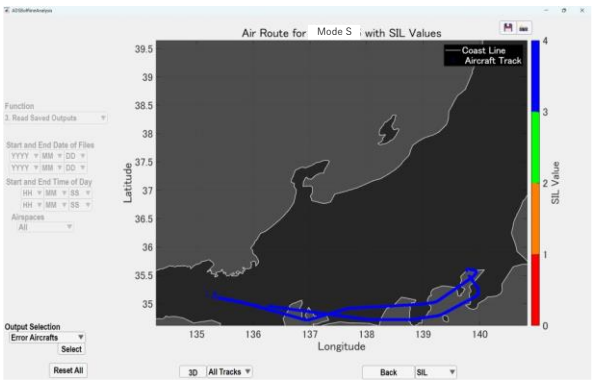


Figure 14 SIL values along the trajectories of a failure aircraft

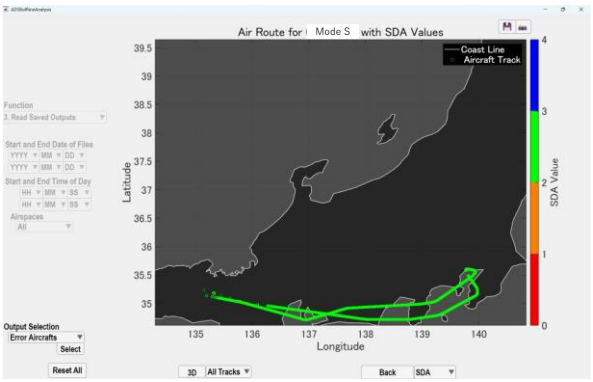
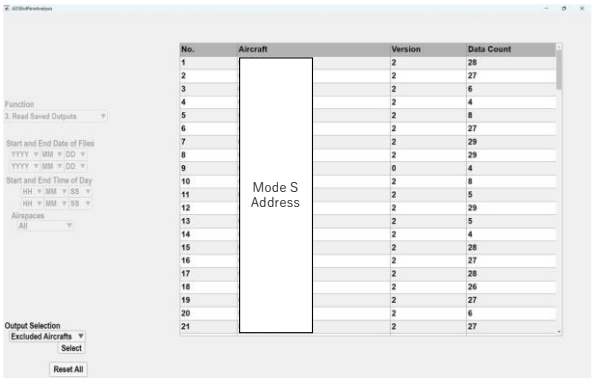


Figure 15 SDA values along the trajectories of a failure aircraft

2.10 Figure 16 shows a list of excluded aircraft, each of which transmitted fewer than 100 signals during the observation period. Figure 17 illustrates the NIC quality of ADS-B, with red indicating ADS-B aircraft with reliability below 99.9 percent.



No.	Aircraft	Version	Data Count
1		2	28
2		2	27
3		2	6
4		2	4
5		2	8
6		2	27
7		2	29
8		2	29
9		0	4
10		2	8
11		2	5
12		2	29
13		2	5
14		2	4
15		2	28
16		2	27
17		2	28
18		2	26
19		2	27
20		2	6
21		2	27

Figure 16 Excluded aircraft list

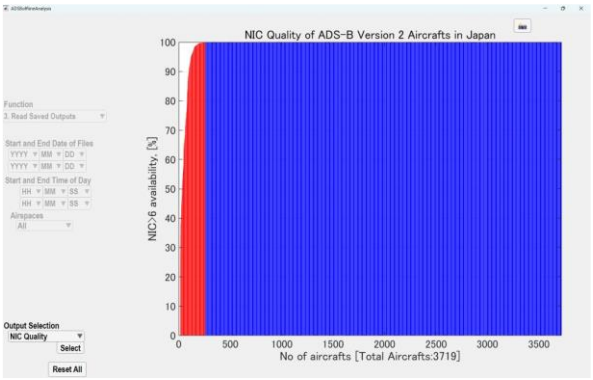
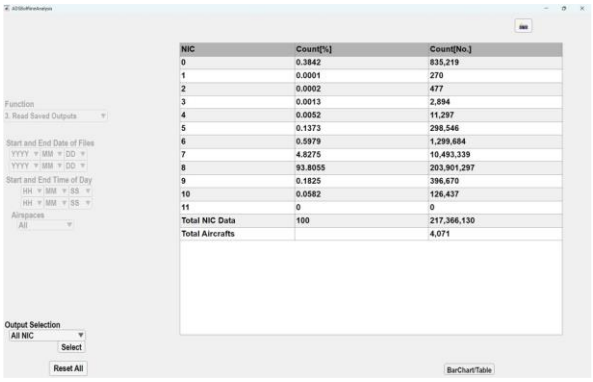


Figure 17 NIC quality of ADS-B

2.11 Figures 18 and 19 show the results of statistical analysis regarding NIC for all ADS-B versions. The values for ADS-B version 0 were converted using the table provided in Doc9871. Figures 20 and 21 show the results of statistical analysis regarding NACp for all ADS-B versions.



NIC	Count[%]	Count[No.]
0	0.3842	835,219
1	0.0001	270
2	0.0002	477
3	0.0013	2,894
4	0.0052	11,297
5	0.1373	298,546
6	0.5979	1,299,684
7	4.8275	10,493,339
8	93.8055	203,901,297
9	0.1825	396,670
10	0.0582	126,437
11	0	0
Total NIC Data	100	217,366,130
Total Aircrafts		4,071

Figure 18 Results of NIC statistical analysis for versions 0 to 2 (table format)

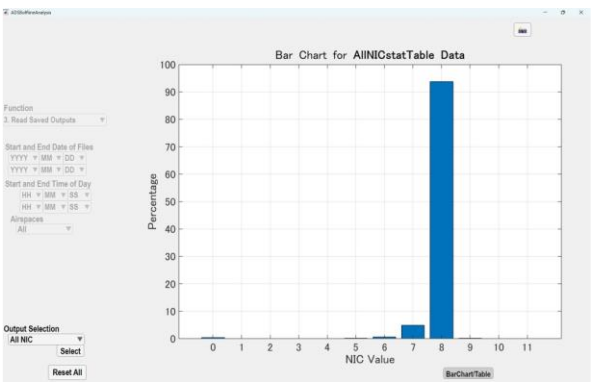
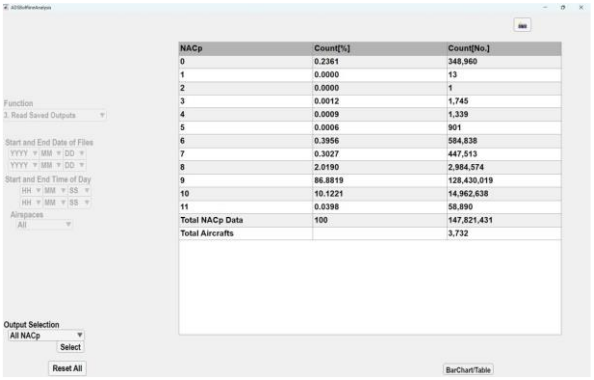


Figure 19 Results of NIC statistical analysis for versions 0 to 2 (bar chart format)



NACp	Count[%]	Count[No.]
0	0.2361	348,960
1	0.0000	13
2	0.0000	1
3	0.0012	1,745
4	0.0009	1,339
5	0.0006	901
6	0.3956	584,838
7	0.3027	447,513
8	2.0190	2,984,574
9	86.8819	128,430,019
10	10.1221	14,962,638
11	0.0398	58,890
Total NACp Data	100	147,821,431
Total Aircrafts		3,732

Figure 20 Results of NACp statistical analysis for versions 0 to 2 (table format)

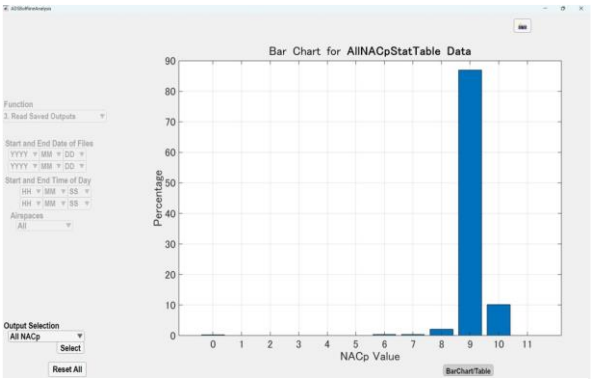


Figure 21 Results of NACp statistical analysis for versions 0 to 2 (bar chart format)

2.12 Finally, the results of statistical analyses for ADS-B version 2 are shown in Figures 22 to 25. Values that meet the requirements are indicated in green, while values below the requirements are indicated in red. Figures 22 and 23 show the results for NIC, and Figures 24 and 25 show the results for NACp. In both cases, over 99 percent of the ADS-B messages satisfied the requirements.

NIC	Count[%]	Count[No.]
0	0.2494	368,028
1	0.0001	110
2	0.0003	476
3	0.0020	2,894
4	0.0066	9,713
5	0.2002	295,411
6	0.4920	725,886
7	0.4343	640,801
8	98.3628	145,136,701
9	0.1935	285,547
10	0.0589	86,920
11	0	0
NIC<7 Data	0.9505	1,402,518
NIC>=7 Data	99.0495	146,149,969
Total NIC Data	100	147,552,487
Total Aircrafts		3,719

Figure 22 Results of NIC statistical analysis for version 2 (table format)

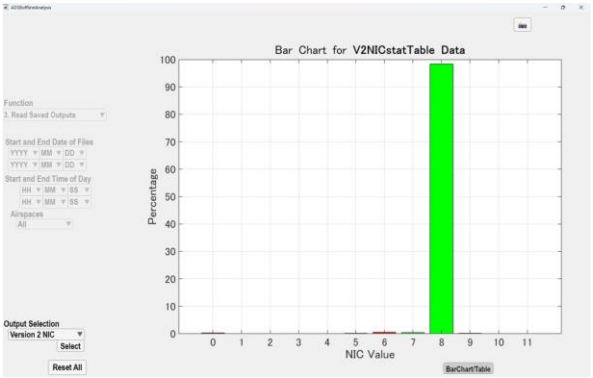


Figure 23 Results of NIC statistical analysis for version 2 (bar chart format)

NACp	Count[%]	Count[No.]
0	0.2276	335,645
1	0.0000	13
2	0.0000	1
3	0.0012	1,745
4	0.0009	1,339
5	0.0006	901
6	0.3966	584,838
7	0.2229	328,705
8	2.0174	2,975,177
9	86.9717	128,263,790
10	10.1212	14,926,577
11	0.0399	58,890
NACp<8 Data	0.8497	1,253,187
NACp>=8 Data	99.1503	146,224,434
Total NACp Data	100	147,477,621
Total Aircrafts		3,719

Figure 24 Results of NACp statistical analysis for version 2 (table format)

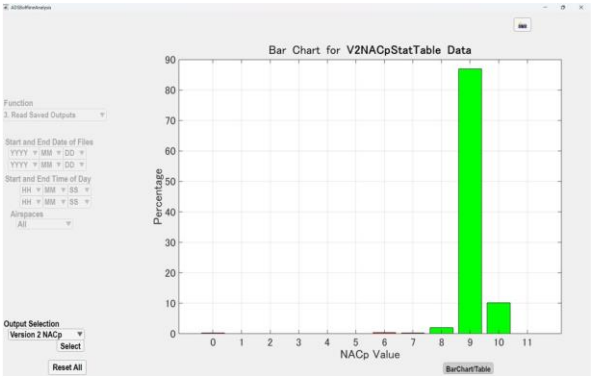


Figure 25 Results of NACp statistical analysis for version 2 (bar chart format)

2.13 This IP introduced the current status of the developed software for evaluating ADS-B performance. The initial development has been completed, and additional functionalities will be implemented if necessary. Future work includes enabling real-time processing capabilities in the software.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper.

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