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

PRELIMINARY ANALYSIS OF ADS-B POSITIONAL PERFORMANCE IN JAPAN

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SUMMARY

This paper provides details of the transition of equipage of ADS-B versions and preliminary results of the statistical analysis of NIC and NACp values as ADS-B positional performance, using data collected in the vicinity of Sendai airport, Japan.

1. INTRODUCTION

1.1 The Japan Civil Aviation Bureau (JCAB) plans to use ADS-B for ATC operations and is evaluating ADS-B performance. ADS-B messages contain positional performance indexes of Navigation Integrity Category (NIC) and Navigation Accuracy Category - Position (NACp). To use ADS-B for aircraft surveillance, NIC and NACp values must meet operational performance requirements. The FAA has mandated the installation of ADS-B version 2 equipment in 2020 and requires ADS-B positional performance as follows [1]:

- The aircraft's NIC must be <0.2 nautical miles; NIC ≧ 7
- The aircraft's NACp must be <0.05 nautical miles; NACp ≧ 8

1.2 To evaluate the ADS-B positional performance, we analyzed NIC and NACp data collected by an ADS-B receiver located in the vicinity of Sendai airport. The analyzed ADS-B data were collected every January from 2017 to 2022 (The data of January 2022 covered only 26 days owing to the shutdown of the data collection system). Analyzed results were presented in ASWG17 in March 2023 [2]. In this paper, we review the above IP and present the transition of the equipage of the ADS-B versions and statistical results of positional data for NIC and NACp values in Japan.

2. DISCUSSION

2.1 Equipage of ADS-B for each version

2.1.1. The numbers of aircraft for each January are shown in Table 1. The numbers are presented for ADS-B versions 0, 1, 2 and the total. The total number of aircraft decreased between January 2020 and January 2021, presumably due to COVID-19.

Table 1. Number of Aircraft

# of aircraft	Total	Ver.0	Ver.1	Ver.2
Jan. 2017	2,664	1,893	183	588
Jan. 2018	2,791	1,765	179	847
Jan. 2019	3,228	1,817	128	1,283
Jan. 2020	3,594	1,281	33	2,280
Jan. 2021	1,937	534	8	1,395
Jan. 2022	2,117	589	5	1,523

2.1.2. The numbers and percentages of aircraft for each ADS-B version are presented in Fig. 1. The percentage of aircraft equipped with ADS-B versions 0 and 1 declined from January 2017 to January 2022, whereas the percentage of aircraft equipped with ADS-B version 2 increased from 22% in January 2017 to 72% in January 2022.

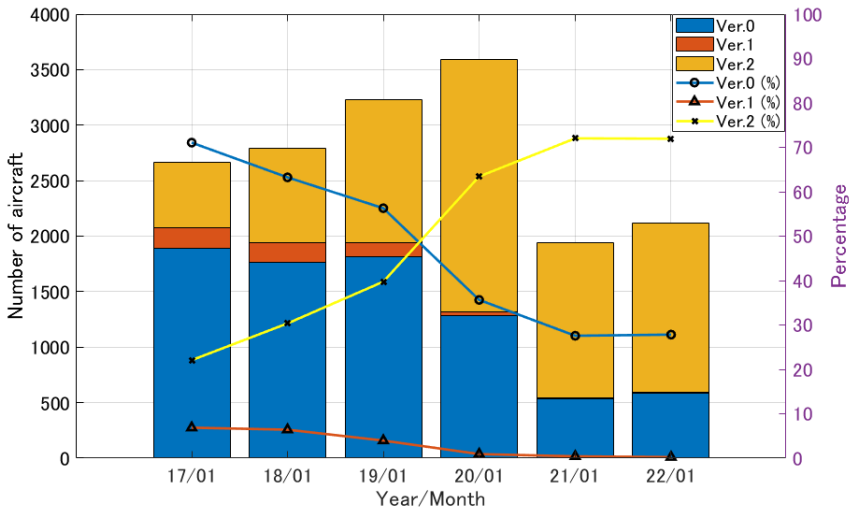

Fig. 1. Numbers and percentages of aircraft for each ADS-B version

2.2 NIC/NACp analysis (ADS-B version 2)

2.2.1. Positional data (AP: Airborne Position and SP: Surface Position) for each of the NIC and NACp values are enumerated in Tables 2 and 3, respectively. Their percentages relative to the totals are also indicated. Regarding the NIC values, the percentages of NIC = 8 were the highest and exceeded 95% throughout the data collection period. The percentages of NIC ≦ 6 were less than 0.05%. Regarding the NACp values, the percentages of NACp = 9 were the highest at ~80% throughout the data collection period. The percentages of NACp ≦ 7 were less than 0.10%.

Table 2. Number of positional data for each NIC value (Total: AP + SP)

NIC	0	1	2	3	4	5	6	7	8	9	10	11
Jan. 2017	261	14	41	13	1	49	2,941	280,568	9,478,602	14,347	0	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.03%)	(2.87%)	(96.95%)	(0.15%)	(0.00%)	(0.00%)
Jan. 2018	1,379	27	0	0	2	3	4,759	389,263	14,216,771	52,116	0	0
	(0.01%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.03%)	(2.65%)	(96.95%)	(0.36%)	(0.00%)	(0.00%)
Jan. 2019	246	37	0	0	2	1	4,045	337,013	19,539,345	436,995	0	1
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.02%)	(1.66%)	(96.17%)	(2.15%)	(0.00%)	(0.00%)
Jan. 2020	4,192	0	0	0	34	4	5,650	303,060	35,978,365	1,192,206	24,319	0
	(0.01%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.02%)	(0.81%)	(95.92%)	(3.18%)	(0.06%)	(0.00%)
Jan. 2021	5,033	1	1	0	8	8	1,125	95,587	20,393,032	88,171	13,029	0
	(0.02%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.01%)	(0.46%)	(99.01%)	(0.43%)	(0.06%)	(0.00%)
Jan. 2022	6,325	9	0	0	3	0	1,290	90,111	28,386,931	27,127	20,705	0
	(0.02%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.32%)	(99.49%)	(0.10%)	(0.07%)	(0.00%)

Table 3. Number of positional data for each NACp value (Total: AP + SP)

NACp	0	1	2	3	4	5	6	7	8	9	10	11
Jan. 2017	271	0	6,303	0	0	0	5	16	38,023	8,122,873	1,590,001	0
	(0.00%)	(0.00%)	(0.06%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.39%)	(83.25%)	(16.30%)	(0.00%)
Jan. 2018	975	0	0	0	0	0	0	184	161,939	12,183,886	2,224,075	0
	(0.01%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(1.11%)	(83.62%)	(15.26%)	(0.00%)
Jan. 2019	67	0	0	4	0	0	0	0	256,884	16,767,774	3,152,077	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(1.27%)	(83.10%)	(15.62%)	(0.00%)
Jan. 2020	414	0	0	0	0	0	0	66	668,298	30,142,788	6,594,435	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(1.79%)	(80.58%)	(17.63%)	(0.00%)
Jan. 2021	113	0	0	0	0	0	0	13	114,424	16,218,052	3,425,326	668,369
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.56%)	(79.40%)	(16.77%)	(3.27%)
Jan. 2022	52	0	0	0	0	0	0	0	127,899	21,712,404	6,437,313	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.45%)	(76.78%)	(22.76%)	(0.00%)

2.2.2. In the next step, we analyzed the NIC and NACp values of only surface positional data to assess the effect of the airport surface and buildings. ADS-B positional data are derived from an onboard GPS receiver. Multipath or shadowing of GPS signals caused by obstacles could result in a decline in positional performance. The numbers and percentages of SP for the NIC and NACp values are presented in Tables 4 and 5, respectively. Note that the sentries of SP data were less than 1.5% of those of AP and SP data.

2.2.3. Regarding the NIC values of SP, the percentages of NIC = 8 were the highest as well as in the case of AP and SP. However, the percentage of NIC = 6 was up to 0.14% in January 2020, and there was only one NIC = 10. The degradation might be attributable to the obstacles of the airport. Additionally, the percentages of NIC = 0 (Integrity unknown) exceeded those of AP and SP, which was possibly attributable to instability when the equipment started running. Regarding the NACp values of SP, the percentages of NACp = 9 were lower than those of AP and SP, whereas the percentages of NACp = 10 exceeded those of AP and SP. The reason remains to be investigated.

Table 4. Number of positional data for each NIC value (only SP)

NIC	0	1	2	3	4	5	6	7	8	9	10	11
Jan. 2017	25	0	0	0	0	0	0	5	10,929	629	0	0
	(0.22%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.04%)	(94.31%)	(5.43%)	(0.00%)	(0.00%)
Jan. 2018	3	0	0	0	0	0	0	583	70,945	3,758	0	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.77%)	(94.23%)	(4.99%)	(0.00%)	(0.00%)
Jan. 2019	226	0	0	0	0	0	91	213	129,673	3,304	0	1
	(0.17%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.07%)	(0.16%)	(97.13%)	(2.47%)	(0.00%)	(0.00%)
Jan. 2020	1,240	0	0	0	0	0	393	1,613	224,493	63,346	0	0
	(0.43%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.14%)	(0.55%)	(77.12%)	(21.76%)	(0.00%)	(0.00%)
Jan. 2021	966	0	0	0	0	0	336	329	295,721	12	0	0
	(0.32%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.11%)	(0.11%)	(99.45%)	(0.00%)	(0.00%)	(0.00%)
Jan. 2022	1,295	0	0	0	0	0	348	678	264,690	18	1	0
	(0.48%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.13%)	(0.25%)	(99.12%)	(0.01%)	(0.00%)	(0.00%)

Table 5. Number of positional data for each NACp value (only SP)

NACp	0	1	2	3	4	5	6	7	8	9	10	11
Jan. 2017	25	0	0	0	0	0	0	0	0	2,003	8,871	0
	(0.23%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(18.38%)	(81.39%)	(0.00%)
Jan. 2018	0	0	0	0	0	0	0	0	0	11,444	59,939	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(16.03%)	(83.97%)	(0.00%)
Jan. 2019	0	0	0	0	0	0	0	0	221	43,822	83,651	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.17%)	(34.32%)	(65.51%)	(0.00%)
Jan. 2020	0	0	0	0	0	0	0	17	0	117,629	155,666	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.01%)	(0.00%)	(43.04%)	(56.96%)	(0.00%)
Jan. 2021	0	0	0	0	0	0	0	0	0	127,047	86,739	66,916
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(45.26%)	(30.90%)	(23.84%)
Jan. 2022	0	0	0	0	0	0	0	0	432	136,948	104,732	0
	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.18%)	(56.56%)	(43.26%)	(0.00%)

2.2.4. The percentages of data for the NIC and NACp values are shown in Figs. 2 and 3, respectively. The blue lines indicate the AP and SP percentages and the red lines indicate those of SP only. Note that the scales of the vertical axes differ for NIC and NACp values.

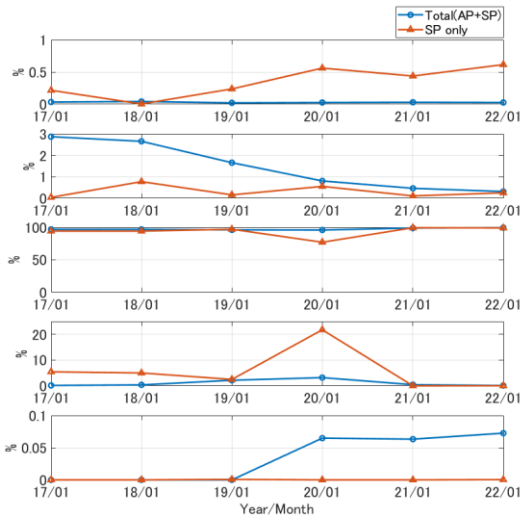

Fig.2 Percentage of positional data for each NIC value

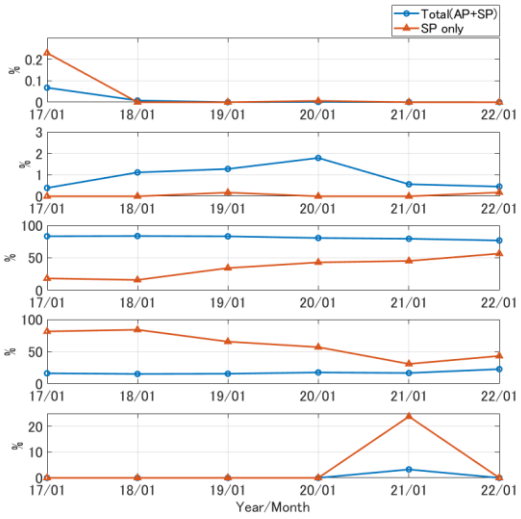

Fig.3 Percentage of positional data for each NACp value

3. SUMMARY

3.1 ADS-B (version 2) positional performances (NIC and NACp) were analyzed for the data collected every January from 2017 through 2022 in the vicinity of Sendai airport. The percentages of aircraft equipped with ADS-B version 2 increased from 22% in January 2017 to 72% in January 2022.

3.2 The NIC values of 99.95% of positional data exceeded 6. The NACp values exceeded 7 for 99.90%. We analyzed the positional performance of the surface positional data alone to assess the effect of the airport surface and buildings. Further analyses will be performed to investigate the causes of positional performance degradation.

4. ACTION BY THE MEETING

4.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matter as appropriate

References

[1] § 91.227 Automatic Dependent Surveillance - Broadcast (ADS-B) Out equipment performance requirements Federal Regulations 14 CFR 91.227, FAA.
[2] K. Matsunaga and J. Honda, “Preliminary Analysis of ADS-B Positional Performance in Japan,” ICAO SP-ASWG17-IP/05, Singapore/Virtual, March 2023.

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