International Civil Aviation Organization

Seventh Meeting of the Surveillance Implementation Coordination Group (SURICG/7)

Video Teleconference, 24 – 27 May 2022

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

ADS-B EQUIPAGE AND QUALITY PERFORMANCE IN THE U.S.

(Presented by United States/Federal Aviation Administration)

SUMMARY

This paper provides a summary of observed NIC/NACp performance compared to the requirements of the U.S. ADS B mandate, as well as ADS-B equipage trends in the U.S.

1. INTRODUCTION

1.1 As context for the information in this paper, the scope of U.S. ADS-B monitoring should be understood. The U.S. has ADS-B ground stations located in the 48 conterminous states, Alaska, Hawaii, as well as the following U.S. territories: Puerto Rico, U.S. Virgin Islands, Guam, and the Commonwealth of the Northern Mariana Islands. In addition, the U.S. receives ADS-B data from three ADS-B ground stations in Mexico, through a cooperative agreement with Mexico's ANSP. Maps showing the totality of this coverage at a typical turbine-powered aircraft flight level (FL350) are shown in Attachment 1. Note that this coverage extends somewhat beyond the airspace where the U.S. ADS-B mandate (14 CFR 91.225) applies.

1.2 During the most recent two-month analysis window ending on 9 April 2022, almost 30% (2,680 out of 9,077) of the observed aircraft were not registered in the U.S.

2. DISCUSSION

2.1 Observed NIC/NACp performance compared to 14 CFR 91.227 requirements

2.1.1 The FAA's ADS B Performance Monitor (APM) automatically generates a report used to analyse how well ADS-B Version 2 systems installed on aircraft are meeting the requirements of the U.S. ADS-B mandate. This paper only discusses the performance of air carrier aircraft; the FAA focuses on air carrier aircraft since general aviation aircraft with ADS-B Version 2 systems usually have Satellite-based Augmentation System (SBAS) position sources.

2.1.2 As used in this paper, "operational availability" is defined as the percentage of time that a system or service is available at the expected level of performance, relative to its expected use. In this paper, the term "outage" typically refers to the system or service dropping below the expected level of performance (versus complete failure of the system or service). Since FAA ATC applications operate at all times, the expected use period does not end. Therefore, 100% operational availability would be a system or service which is continually available at the expected level of performance during the entire

measurement period. Traditionally, the FAA has used an operational availability requirement of greater than or equal to 99.9% for engineering FAA ATC surveillance systems. This allows a maximum surveillance "outage" duration of 0.1%, which is about 86 seconds during a given 24-hour period (or almost 9 hours per year). The analysis results discussed in this paper proceed with this surveillance requirement in mind.

2.1.3 In the tables below, red shading indicates that the ADS-B position quality is insufficient for the ADS-B data to be used by ATC, green shading indicates that the ADS-B position quality meets the requirements of 14 CFR 91.227, and yellow shading indicates that the ADS-B data may be used by ATC but is insufficient to support 3 nm or closer separation minima. Therefore, for FAA to consistently support 3 nm separation in en route airspace below FL230 using ADS-B data, aircraft must produce "green shading" performance most of the time.

2.1.4 The table below is the NIC performance analysis for the two-year period ending 9 April 2022.

Radius of Containment (Rc)	NIC	2 months ending 9-Jun-2020	2 months ending 9-Aug-2020	2 months ending 9-Oct-2020	2 months ending 9-Dec-2020	2 months ending 9-Feb-2021	2 months ending 9-Apr-2021	2 months ending 9-Jun-2021	2 months ending 9-Aug-2021	2 months ending 9-Oct-2021	2 months ending 9-Dec-2021	2 months ending 9-Feb-2022	2 months ending 9-Apr-2022
Rc unknown	0	0.0123%	0.0146%	0.0139%	0.0111%	0.0131%	0.0130%	0.0098%	0.0136%	0.0183%	0.0357%	0.0166%	0.0104%
Rc < 20 nm	1	0.0001%	0.0002%	0.0001%	0.0001%	0.0000%	0.0002%	0.0001%	0.0003%	0.0002%	0.0001%	0.0001%	0.0001%
Rc < 8 nm	2	0.0001%	0.0004%	0.0002%	0.0001%	0.0001%	0.0002%	0.0001%	0.0003%	0.0004%	0.0003%	0.0002%	0.0001%
Rc < 4 nm	3	0.0003%	0.0005%	0.0003%	0.0002%	0.0001%	0.0004%	0.0001%	0.0003%	0.0006%	0.0003%	0.0003%	0.0002%
Rc < 2 nm	4	0.0004%	0.0010%	0.0006%	0.0003%	0.0004%	0.0007%	0.0003%	0.0006%	0.0009%	0.0006%	0.0005%	0.0004%
Rc < 1 nm	5	0.0004%	0.0012%	0.0007%	0.0005%	0.0004%	0.0009%	0.0004%	0.0008%	0.0011%	0.0008%	0.0007%	0.0004%
Rc < 0.6 nm	6(0)	0.0002%	0.0006%	0.0005%	0.0003%	0.0003%	0.0007%	0.0006%	0.0004%	0.0006%	0.0005%	0.0005%	0.0002%
Rc < 0.5 nm	6(1)	0.0013%	0.0039%	0.0033%	0.0063%	0.0027%	0.0054%	0.0138%	0.0033%	0.0033%	0.0034%	0.0084%	0.0025%
Rc < 0.3 nm	6(2)	0.1390%	0.2174%	0.1475%	0.0795%	0.0553%	0.1037%	0.1434%	0.1826%	0.1382%	0.1257%	0.0976%	0.0294%
	6 (Sum)	*0.1409%*	*0.2231%*	*0.1521%*	*0.0866%*	*0.0587%*	*0.1106%*	*0.1583%*	*0.1871%*	*0.1432%*	*0.1305%*	*0.1072%*	*0.0326%*
Rc < 0.2 nm	7	5.1634%	7.4737%	6.2335%	5.0953%	4.0138%	4.9303%	5.3641%	4.9668%	4.8961%	4.8395%	5.3147%	4.7623%
Rc < 0.1 nm	8	94.6267%	92.2413%	93.5472%	94.7531%	95.8414%	94.8882%	94.4123%	94.7789%	94.8821%	94.9455%	94.5072%	95.1423%
Rc < 75 m	9	0.0558%	0.0452%	0.0522%	0.0533%	0.0724%	0.0536%	0.0461%	0.0410%	0.0496%	0.0411%	0.0462%	0.0473%
Rc < 25 m	10	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0028%	0.0088%	0.0110%	0.0085%	0.0063%	0.0069%	0.0044%
Rc < 7.5 m	11	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
# reports		4.857E+09	5.991E+09	6.576E+09	6.263E+09	7.274E+09	7.305E+09	8.913E+09	1.119E+10	1.098E+10	9.612E+09	1.100E+10	1.120E+10
# aircraft		6,626	6,888	7,203	7,512	7,729	7,896	8,123	8,542	8,746	8,918	9,027	9,077
reports/aircrft		732,993	869,816	913,013	833,727	941,091	925,138	1,097,292	1,310,496	1,255,839	1,077,804	1,218,254	1,233,446
	<7	0.1540%	0.2398%	0.1671%	0.0984%	0.0724%	0.1251%	0.1687%	0.2023%	0.1637%	0.1676%	0.1250%	0.0438%

2.1.5 Although the number of air carrier aircraft included in the analysis has fluctuated considerably over the two-year period (between 6,626 and 9,077 aircraft), the NIC results are relatively consistent over the analysis period. Note that once NIC falls below 6, the most likely value to be reported is NIC=0.

2.1.6 The table below is the NACp performance analysis for the two-year period ending 9 April 2022.

Est Position Uncertainty	NACp	2 months ending 9-Jun-2020	2 months ending 9-Aug-2020	2 months ending 9-Oct-2020	2 months ending 9-Dec-2020	2 months ending 9-Feb-2021	2 months ending 9-Apr-2021	2 months ending 9-Jun-2021	2 months ending 9-Aug-2021	2 months ending 9-Oct-2021	2 months ending 9-Dec-2021	2 months ending 9-Feb-2022	2 months ending 9-Apr-2022
EPU >= 10 nm	0	0.0024%	0.0061%	0.0070%	0.0053%	0.0047%	0.0055%	0.0040%	0.0071%	0.0110%	0.0080%	0.0050%	0.0055%
EPU < 10 nm	1	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%	0.0000%	0.0000%	0.0000%	0.0000%
EPU < 4 nm	2	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%	0.0000%
EPU < 2 nm	3	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%	0.0001%	0.0000%	0.0000%	0.0001%	0.0000%
EPU < 1 nm	4	0.0000%	0.0001%	0.0001%	0.0001%	0.0000%	0.0000%	0.0000%	0.0002%	0.0001%	0.0000%	0.0000%	0.0000%
EPU < 0.5 nm	5	0.0001%	0.0002%	0.0002%	0.0001%	0.0000%	0.0002%	0.0000%	0.0002%	0.0001%	0.0000%	0.0000%	0.0000%
EPU < 0.3 nm	6	0.0005%	0.0010%	0.0005%	0.0002%	0.0002%	0.0008%	0.0004%	0.0009%	0.0011%	0.0005%	0.0005%	0.0004%
EPU < 0.1 nm	7	0.0020%	0.0050%	0.0077%	0.0086%	0.0033%	0.0044%	0.0071%	0.0048%	0.0047%	0.0150%	0.0131%	0.0062%
EPU < 0.05 nm	8	10.8519%	14.5693%	12.1070%	10.2153%	9.4739%	9.9984%	10.2485%	10.3583%	10.1989%	9.8961%	9.8504%	9.7740%
EPU < 30 m	9	58.4054%	59.9364%	59.8830%	59.0738%	58.3670%	57.4094%	56.7015%	55.7895%	54.5780%	54.3724%	54.4698%	54.2634%
EPU < 10 m	10	29.1104%	24.1823%	26.6545%	29.3191%	30.4799%	31.1065%	31.7161%	32.7650%	34.1656%	34.6789%	34.7615%	34.9873%
EPU < 3 m	11	1.6274%	1.2996%	1.3400%	1.3775%	1.6709%	1.4748%	1.3223%	1.0738%	1.0405%	1.0290%	0.8995%	0.9632%
	<8	0.0050%	0.0125%	0.0156%	0.0143%	0.0083%	0.0109%	0.0117%	0.0134%	0.0170%	0.0236%	0.0188%	0.0121%

2.1.7 The overall trends are similar to the NIC analyses results, but it is clear that NACp rule violations are at least an order of magnitude less likely than for NIC. For this and other reasons, NIC performance generally defines the limits for using ADS-B data in ATC operations.

2.1.8 Figure 1 shows the percentage of aircraft in each bimonthly data sample taken since 9-Dec-2019 which failed to meet the previously defined criteria of NIC>6 at or above 99.900%. The dashed line is the Excel-computed trend line and shows a slight decline during the period. It is expected that this trend will continue as air carrier aircraft with newer position sources are introduced (new production aircraft) and as aircraft equipped with GPS SA-On ADS-B position sources are retrofitted with modern position source solutions.

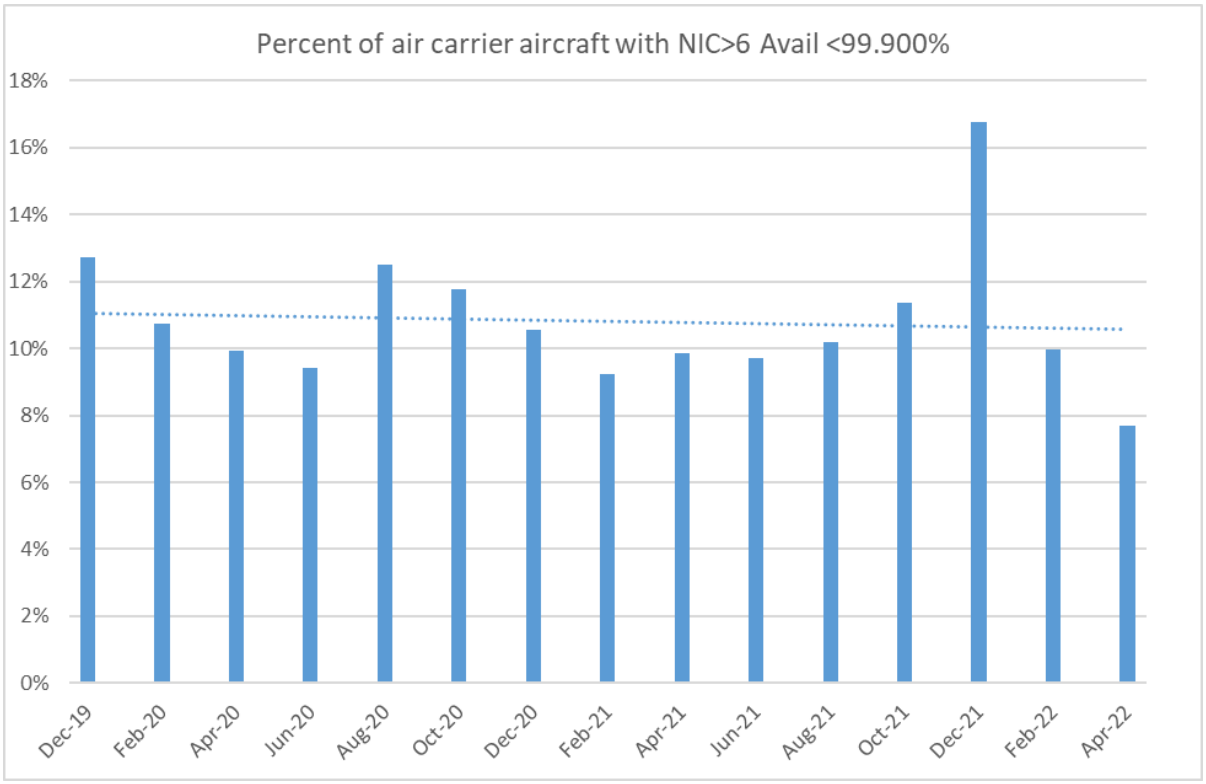

Figure 1 – Percentage of air carrier aircraft not meeting NIC>6 availability criteria

2.2 Tracking ADS B equipage trends in the U.S.

2.2.1 The FAA's ADS-B Performance Monitor (APM) also has various capabilities for tracking ADS-B equipage trends. The APM tracks unique ICAO aircraft addresses and keeps statistics over the past two years. The count of ICAO aircraft addresses is based on the number of detected addresses during the year prior to the count period. For example, the count of ICAO aircraft addresses in July 2018 includes all addresses detected since July 2017. If an ICAO aircraft address is not detected for over a year, it is dropped from the count in the month when that occurs. Note that the APM counts aircraft detected within U.S. ADS-B coverage, regardless of airspace class; therefore, many ADS-B-equipped aircraft are detected which do not fly in the airspace where the U.S. ADS-B mandate applies.

2.2.2 Figure 2 shows the number of aircraft with different ADS B versions since 1 May 2020. During this period, the number of ADS B Version 0 aircraft has decreased from 1,052 to about 340; the number of ADS B Version 1 aircraft has decreased from 658 to about 170. In contrast, ADS B Version 2 aircraft equipage increased from 151,113 to 178,277.

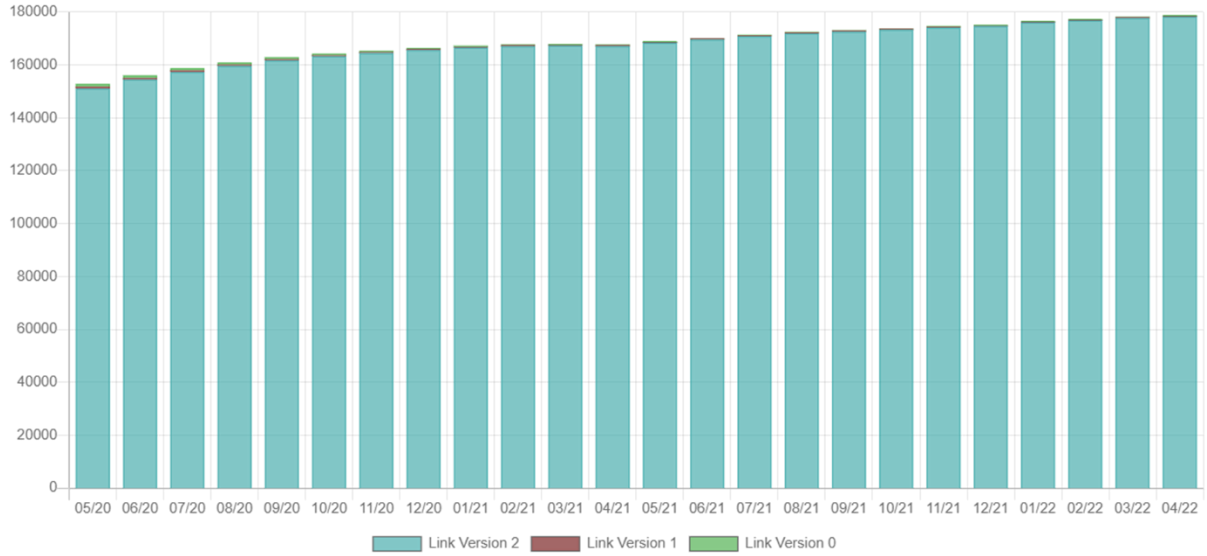

Figure 2 – Aircraft ADS-B Out equipage by ADS-B Version (Link Version)

2.2.3 The APM is also capable of showing data by "link type" – this is useful for understanding the relative fraction of UAT and 1090ES equipage in the U.S. Figure 3 shows the number of aircraft using different ADS-B technologies since 1 May 2020. Since the U.S. allows use of either 1090ES or UAT ADS-B Out devices, the APM tracks these categories, along with a "Dual" category, as some operators have elected to equip their aircraft with both a 1090ES and UAT device to ensure that their aircraft will be "seen" in U.S. airspace where FAA ADS-R service coverage does not exist.

2.2.4 During the period shown, the number of 1090ES-equipped aircraft has increased from 116,872 to 135,221, the number of "Dual"-equipped aircraft has been roughly flat at around 1,300 aircraft, and the number of UAT-equipped aircraft has increased from 32,920 to about 41,740.

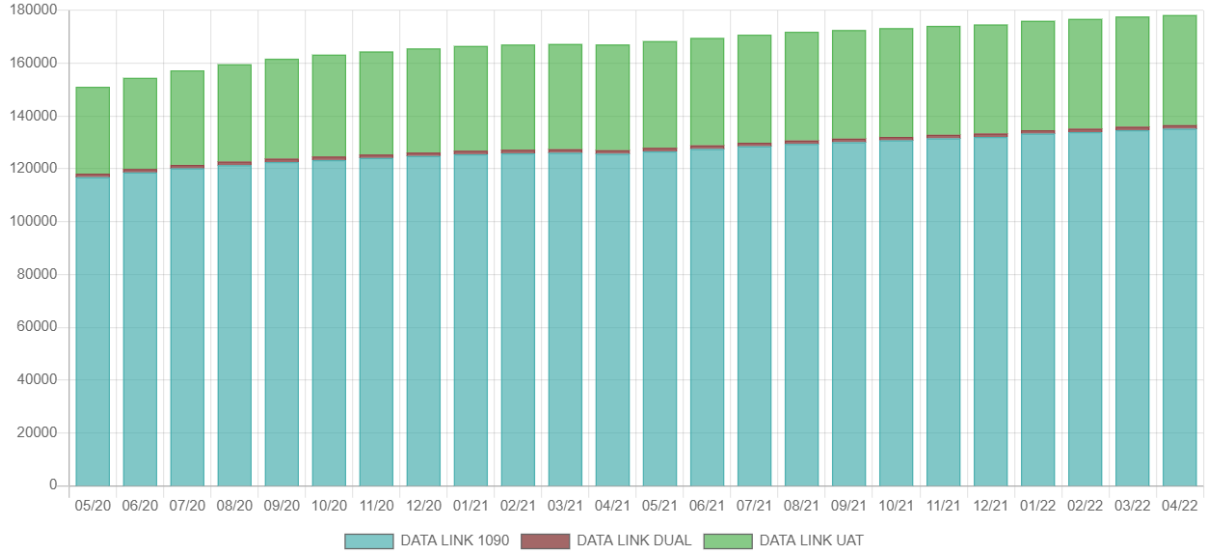

Figure 3 – Aircraft ADS-B Out equipage by ADS-B Link Type (1090ES, UAT, or DUAL)

2.2.5 The APM can also display equipage trends as they impact flight operations. Figure 4 shows the number of operations by different ADS-B versions since 1 May 2020. During this period, the number of ADS-B Version 0 operations has ranged from 677 per month to 293 per month and the number of ADS-B Version 1 operations has ranged from 1,570 per month to 265 per month. In contrast,

the number of ADS-B Version 2 operations has ranged from a low of 1,285,804 per month to a peak of 2,466,626 per month.

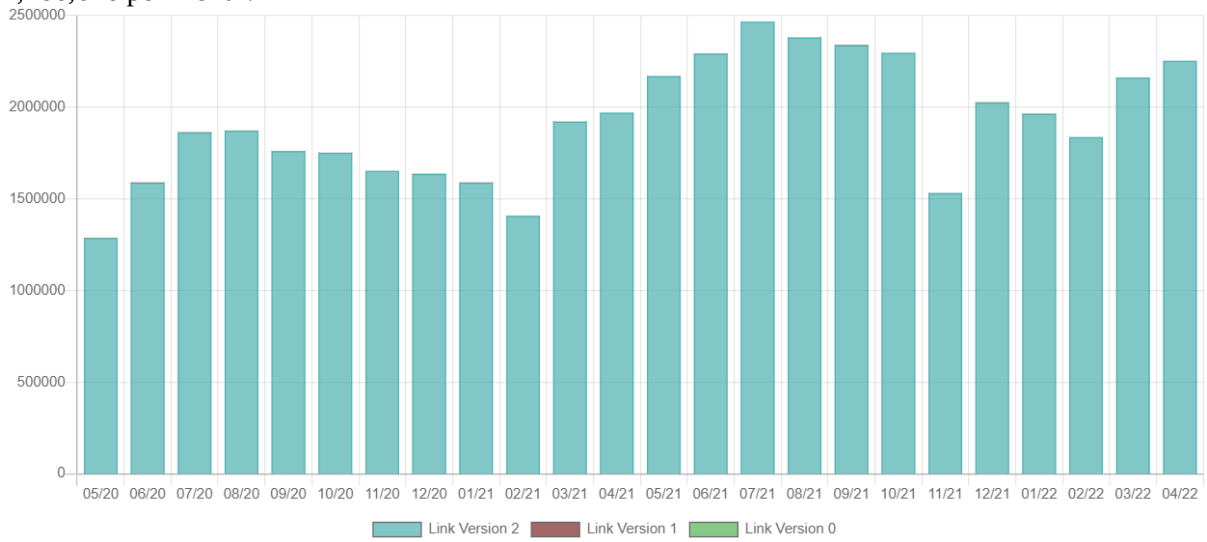

Figure 4 – Aircraft ADS-B Out Operations by ADS-B Version (Link Version)

2.2.6 Figure 5 shows the number of operations by different ADS-B-In link types since 1 May 2020. Since ADS-B Version 1 is incapable of reporting "Dual" In, all "Dual" In configurations are being reported by ADS-B Out Version 2 systems. During this period, the number of 1090ES ADS-B-In operations has ranged from 71,313 per month to 182,619 per month; the number of UAT ADS-B-In operations has ranged from 99,111 per month to 196,806 per month. Meanwhile, the number of Dual-In ADS-B-In operations has ranged from 472,945 per month to 851,797 per month. The seasonal variations seen in this two-year data sample show that most ADS-B-In systems are installed in general aviation aircraft – these aircraft fly more often in the summer than in the winter.

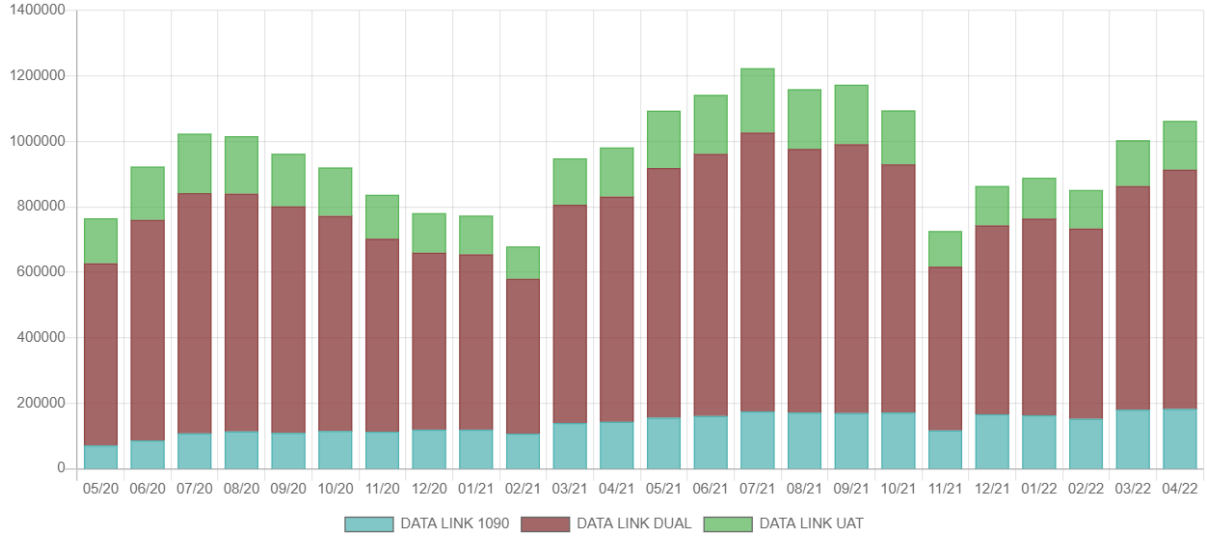

Figure 5 – Aircraft ADS-B In operations by ADS-B Link Type (1090ES, UAT, or DUAL)

3. CONCLUSION

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matters as appropriate.

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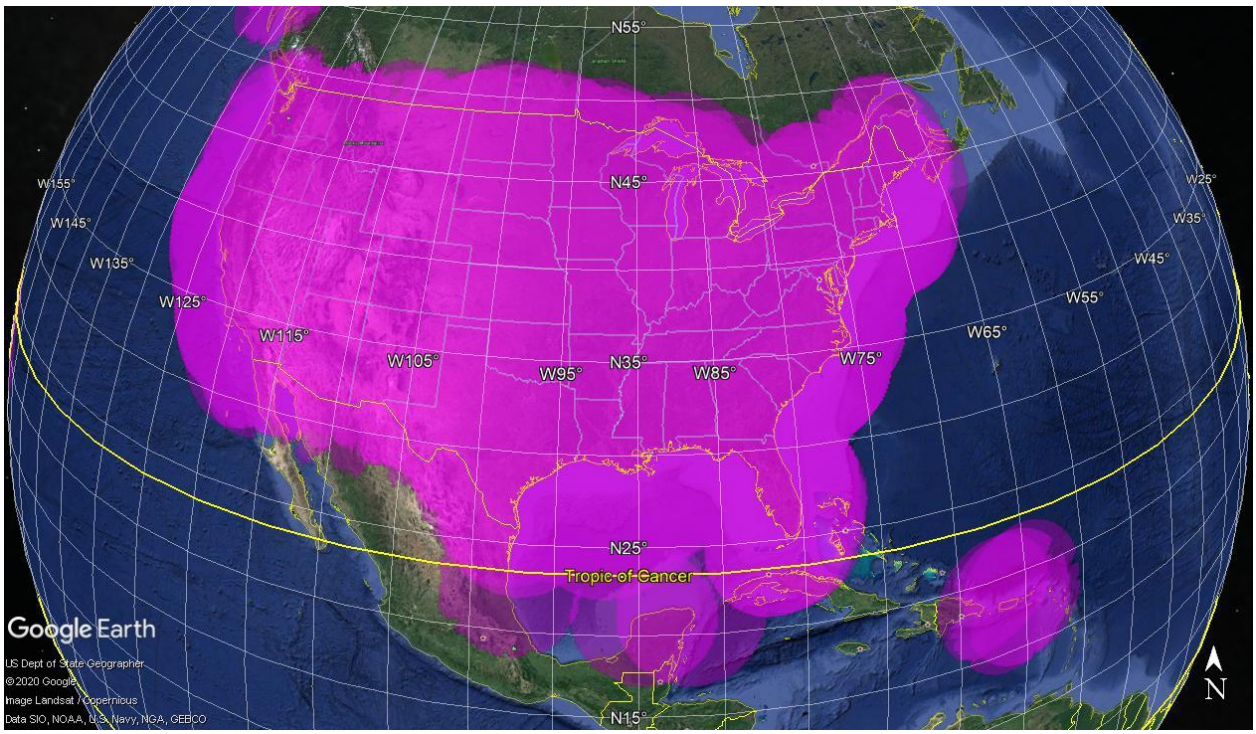
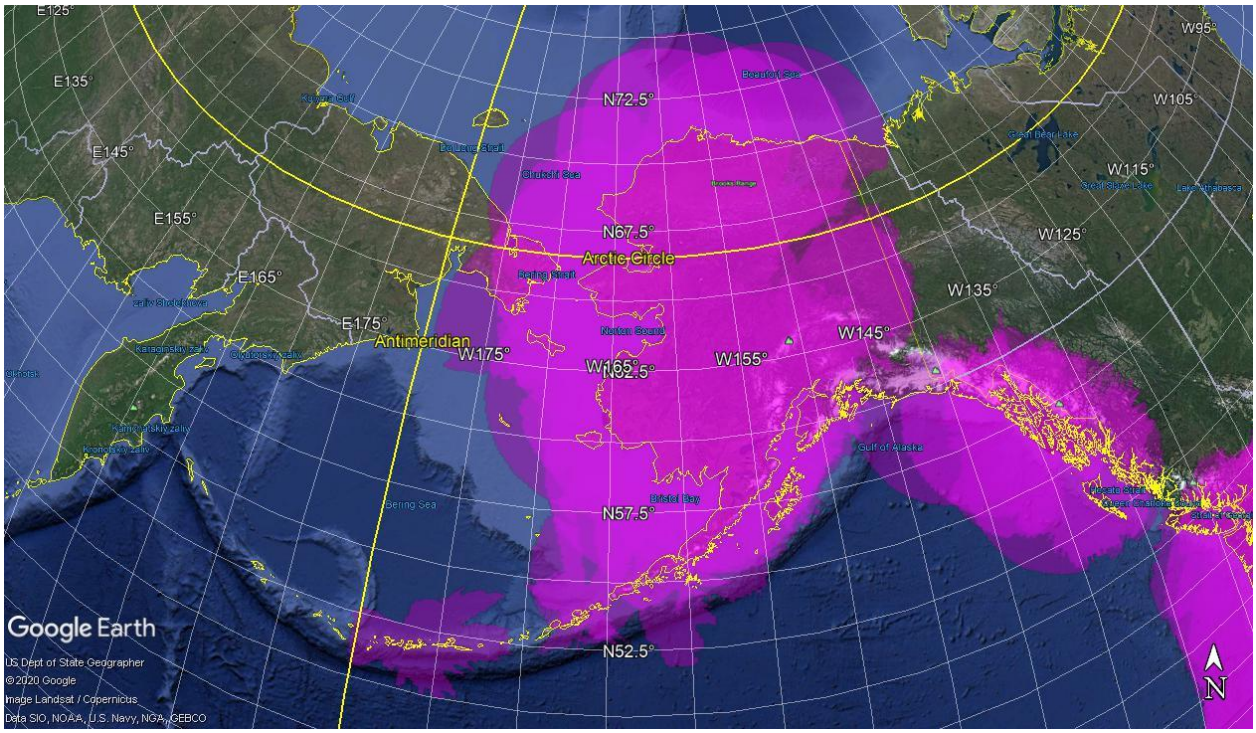
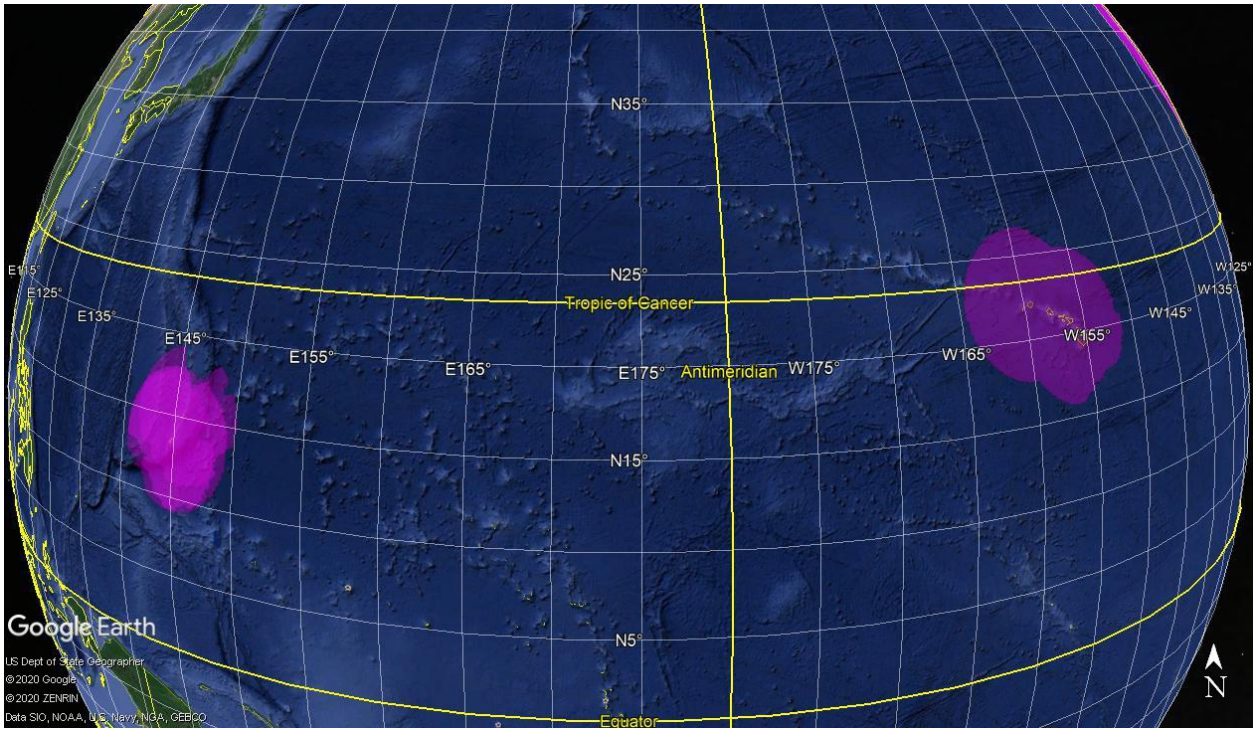
ATTACHMENT 1
FAA ADS-B Coverage at FL350 (shading intensity indicates degree of overlap in coverage)



North America and Puerto Rico/Virgin Islands



Northwestern North America (Alaska)



Guam/CNMI and Hawaii

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