International Civil Aviation Organization

EIGHTH MEETING OF SPECTRUM REVIEW WORKING GROUP (SRWG/8)

Bangkok, Thailand, 05 – 07 March 2024

Agenda Item 7: Frequency Interference in the Region

7.2 GNSS interference

GNSS RADIO FREQUENCY INTERFERENCE: IATA ANALYSIS

(Presented by IATA)

SUMMARY

This paper presents an overview of GNSS radio frequency interference (RFI) and the significance to airline operations.
Reference data for this analysis was derived from the IATA Flight Data Exchange (FDX) with data range from August 2021 to December 2023.

1. INTRODUCTION

1.1 Global Navigation Satellite System (GNSS) is a key enabler of modern aviation providing precise position and timing information and essential inputs to a wide range of aircraft systems. Modern air traffic relies heavily on the accuracy of aircraft systems and an aircraft's ability to monitor its own serviceability. Satellite-based Communications, Navigation and Surveillance (CNS) services play an important part in Air Traffic Management (ATM) with a growing dependence on space-based infrastructure.

1.2 The aviation industry is concerned at elevated levels of GNSS RFI occurring in various regions with increasing numbers of pilot and automated reports, sometimes corelated with conflict zones.

1.3 This working paper explores the implications of such incidents, outlines relevant ICAO and IATA initiatives, and offers a global and Asia-Pacific analysis of airline data obtained by the IATA Flight Data Exchange (FDX) from August 2021 to December 2023.

2. DISCUSSION

2.1 GNSS is based on satellite constellations such as the US Global Positioning System (GPS) and European Galileo infrastructure. Other constellations are also in service and recognized by ICAO. Low power satellite GNSS signals are vulnerable to interference which can be natural (e.g., solar weather related) or artificial (e.g., the use of personal privacy devices) or militarily intentional (e.g., jamming and spoofing).

2.2 Recently, elevated levels of long duration and deliberate military jamming and spoofing has threatened the integrity of Positioning, Navigation, and Timing (PNT) services across several regions. ‘Jamming’ blocks a signal, whereas ‘spoofing’ sends false information to the receiver on board the aircraft.

2.3 IATA recognizes the importance of addressing GNSS RFI and is actively engaged in industry wide collaborative efforts to mitigate associated risks.

2.4 Most recently, the European Union Aviation Safety Agency (EASA) and IATA announced the conclusions of a workshop jointly hosted at EASA's headquarters in Cologne on January 25th, 2024. Over 120 participants from ANSPs, airlines, manufacturers, system suppliers, and institutions joined the in-person event and shared information on reported GNSS RFI events and potential mitigation measures.

2.5 The workshop's high-level conclusion was that interference with satellite-based services can pose significant challenges to aviation safety. Mitigating these risks requires short-, medium- and long-term measures, beginning with the sharing of incident information and remedies. Measures agreed by the workshop to make PNT services provided by GNSS more resilient, include:

- Reporting and sharing of GNSS interference event data. In Europe, this would occur through the European Occurrence Reporting scheme and EASA's Data4Safety program. As this is a global problem, it is important to gain a comprehensive understanding by compiling information currently stored in various databases such as **IATA's Flight Data Exchange (FDX)** and EUROCONTROL's EVAIR. This topic will be included in follow-up discussions among all stakeholders.

- Guidance from aircraft and avionic original equipment manufacturers (OEMs). This will ensure that aircraft operators are appraised of the latest OEM information on mitigation measures. EASA's Safety Information Bulletin (SIB) 2022-02R2 also provides important information for airlines.

- Alerting: EASA will inform relevant stakeholders (airlines, air navigation service providers (ANSPs), manufacturing industry and airports) about RFI incidents.

- Backup: Aviation must retain a Minimum Operational Network (MON) of traditional navigation aids to ensure there is a conventional backup for GNSS navigation.

2.6 IATA FDX Analysis report on GPS Signal loss

The IATA Global FDX Analysis is presented in **APPENDIX A** to this paper. The report uses airline data sourced from August 2021 to December 2023.

2.7 *Conclusion*

GNSS RFI is a significant concern for the aviation industry. Collaborative efforts among regulatory authorities, industry stakeholders, and international organizations is essential to effectively mitigate associated risks. By implementing comprehensive strategies, enhancing regulatory frameworks, and fostering international cooperation, the aviation community can ensure the continued reliability and integrity of PNT systems, thereby enhancing safety and efficiency in air transportation.

Willie Walsh, IATA's Director General at EASA-IATA Workshop:
"We need coordinated collection and sharing of GNSS safety data; universal procedural GNSS incident guidance from aircraft manufacturers; a commitment from States to retain traditional navigation systems as backup in cases where GNSS are spoofed or jammed. In actioning these items, the support and resources of EASA and other governmental authorities are essential. And airlines will be critical partners. And whatever actions are taken, they must be the focal point of the solution as they are the front line facing the risk."

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matter as appropriate.

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GPS Signal Loss

Global FDX Analysis Report

+ Focus on ASPAC region

2021 Aug - 2023 Dec

Produced in February 2024

Foreword and Disclaimer

International Air Transport Association (IATA)

Global Aviation Data Management (GADM) Data Sharing Programs

Flight Data Exchange (FDX)

The International Air Transport Association (**IATA**) Global Aviation Data Management Program's Flight Data Exchange (**FDX**) is a web-based tool intended to provide subscribing members with a comparative overview to highlight areas of flight safety concern, with benchmarking available at a global, regional and airport level.

The data and information lodged on FDX are to the best of our ability reliable, accurate and trustworthy. IATA however does not warrant or express any opinions whatsoever as to the accuracy, origin, tracing, completeness and timeliness of such data and information. Although every effort has been made to ensure accuracy in processing and analyzing flights, IATA shall not be held responsible for any loss or damage caused by errors, omissions, misprints or misinterpretation of the contents hereof. We make no representations, warranties or other assurances, express or implied, about the accuracy, sufficiency, relevance and validity of the data and information captured and reported. Our data collection and reporting are intended to be factual and neutral. FDX AND ITS CONTENTS ARE PROVIDED TO YOU ON AN "AS IS, WHERE IS" BASIS, AND WE DISCLAIM ANY WARRANTY OF MERCHANTABILITY, QUALITY OR FITNESS FOR A PARTICULAR PURPOSE. We expressly disclaim any liability, direct or indirect, to you or any person, for any losses or damages, including without limitation incidental losses, loss of opportunity and damages to reputation, resulting from your access to and use of said contents.

FDX is not intended to replicate or replace the operator's own internal flight data analysis program. As such, airlines can expect to see variation between their own internal flight data program results, and the information collected and analyzed through FDX. The reasons for this are twofold:

- The collection of flight data on a global level requires a broader categorization and definition of event limits and Key Performance Variables.

- Concerning sector counts, FDX makes no guarantee that all flights have been submitted by an airline and that all flights submitted have been processed, which may further result in rate variations.

FDX and its contents are not intended to serve as the sole and exclusive basis for assessment and decision making and constitute one of many means of information gathering at your disposal. You are advised to make your own determination and make your own inquiries and verifications as you may deem necessary and suitable. You shall independently and without solely relying on the information reported, perform your own analysis and evaluation in regards to the nature and level of information you may require, based upon such information, analyses and expert advice as you may deem appropriate and sufficient, and make your own determination and decisions pertaining to the subject matter under consideration.

The information contained in this analysis and on the FDX platform is intended for FDX members only and shall not be communicated, published, shared or distributed in any format to any other party. If you have received this transmission in error, please delete it immediately and notify us by return e-mail at fdx@iata.org

Definitions

Region: Global

Period: 2021 Aug - 2023 Dec

Report Background

This Global FDX Analysis report aims to have a deeper look at the GPS Signal Loss occurrences within the FDX Program to review this on going aviation risk in detail. The report covers flight data analysis results of the FDX Program starting from August 2021 to end of September 2023 and contains specific information about the FDX event frequency in different dimensions such as;

- geographic location,
- occurrence month of the year,
- occurrences time of the day,
- occurrence duration,
- operational phase,
- and aircraft category.

Within the report pages three main measure used to identify the GPS Signal Loss event trend. These measures are namely "FDX Flights" which corresponds the number of flights analyzed, "FDX Events" represents the number of GPS Signal Loss events, and "FDX Rate" shows the frequency of occurrence per 1000 flights.

FDX Event Description

In August 2021, due to the increasing volume of GPS Signal related occurrences a new FDX event algorithm added into the analysis specification files of the FDX Program.
The event named as "GPS Signal Loss" and described as follows. Monitors the time when the parameter GPS operational, mainly derived from the FMC selected navigation source, restricted to airborne state only and triggers for a signal lost of at least 60 seconds or more. Loss of a GPS signal may indicate system failure or interference.

FDX Rule of 3

IATA employs the general “rule-of-three” policy for de-identification purposes. As such, to provide analysis on broad categories such as Region, Aircraft Category, Airport, etc., there must be at least three distinct data contributors for the period under review. For example, at least three participants must have contributed data from each country/region before that country/region is identified in an analysis. Additionally, there must be more than 100 landings in TOTAL at a particular airport for the analysis period (Not per Month basis) for that airport to be included in the analysis report.

FDX Rate

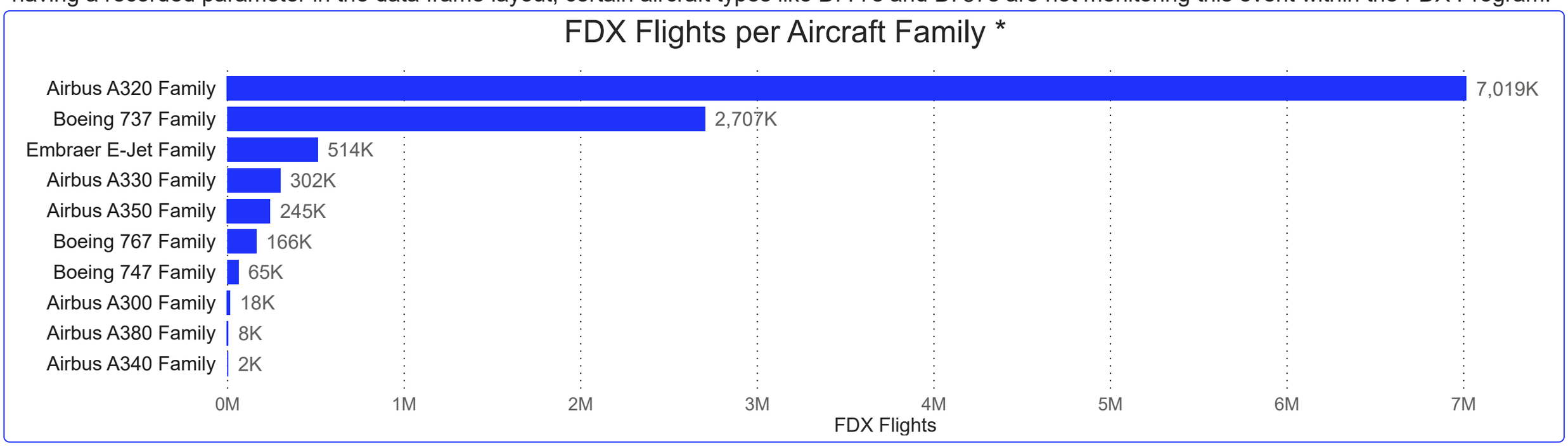
The FDX Rate is normalized per 1,000 FDX Flights and calculated as following for any data point studied in this report.

[Number of Events / Number of Flights] * 1000

Note: Number of Event for a flight with multiple GPS Signal Lost events counted as one when computing the event rate.

Aircraft Family Coverage

During the analysis it has been identified that "GPS Signal Loss" FDX event has been triggered while operating listed aircraft families at least one time for three different operators. Below chart presents registered flights of the FDX Program per aircraft family. Also due to technical limitations such as not having a recorded parameter in the data frame layout, certain aircraft types like B777s and B787s are not monitoring this event within the FDX Program.

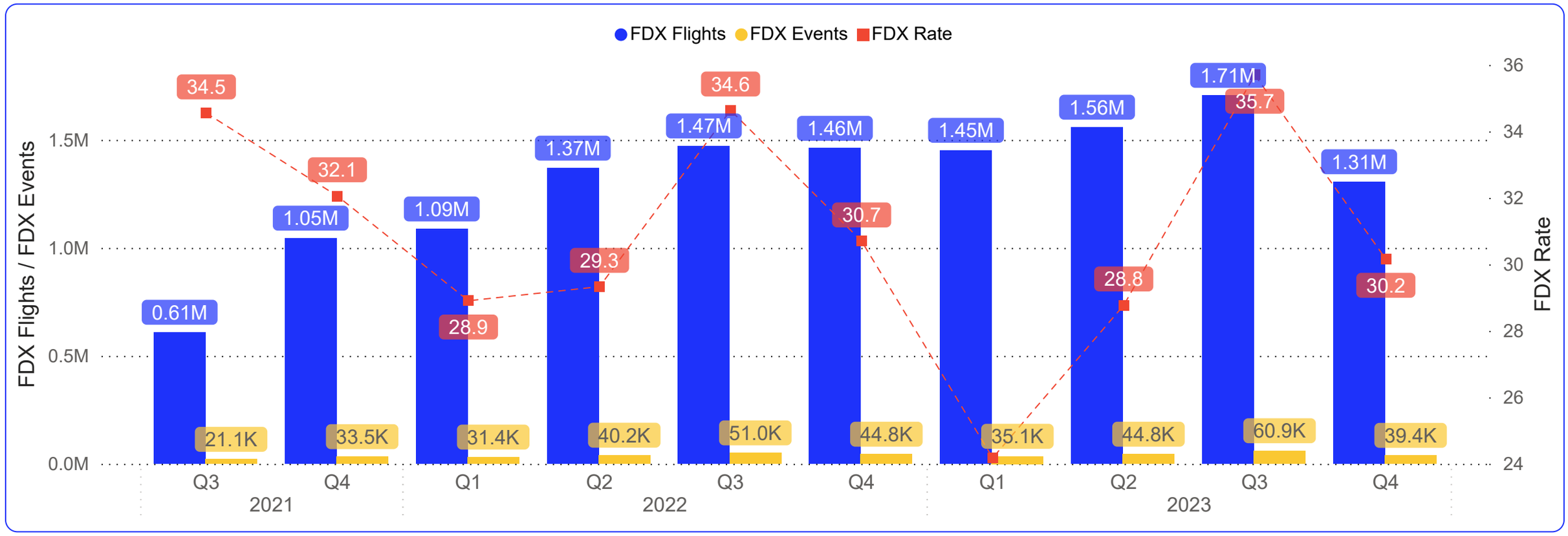


GPS Signal Loss Occurrence Rate

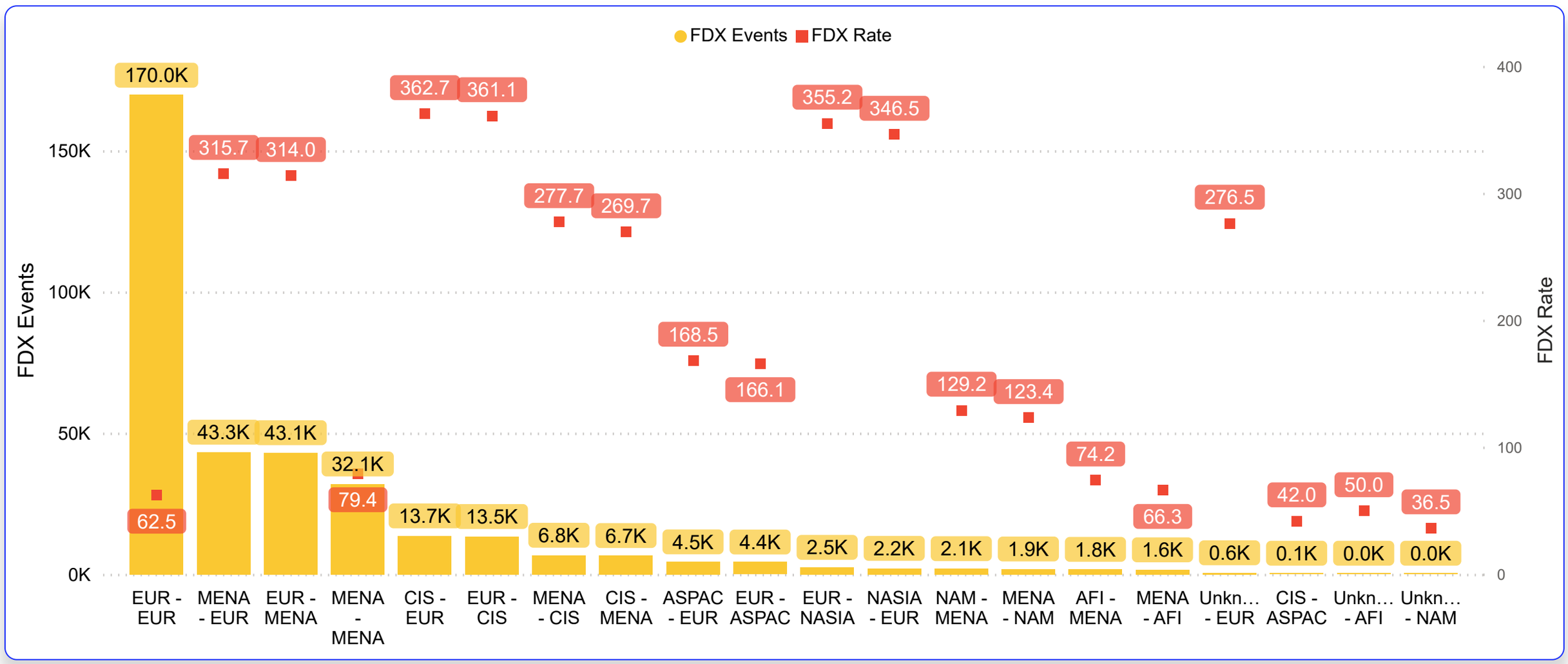
Region: Global

Period: 2021 Aug - 2023 Dec

GPS Signal Loss event has been added into FDX Program algorithms in July 2021. Below chart presents quarterly rate distribution of the GPS Signal Loss event comparative to the total number of flights analyzed and number of events triggered within the FDX Program.



As description GPS Signal Loss event assigned to be activated in airborne state thus the analysis focuses departure and arrival airport pairs and their regions. The following chart presents the count and rate of the GPS Signal Loss event within the TOP 20 most affected routes by FDX Rate.

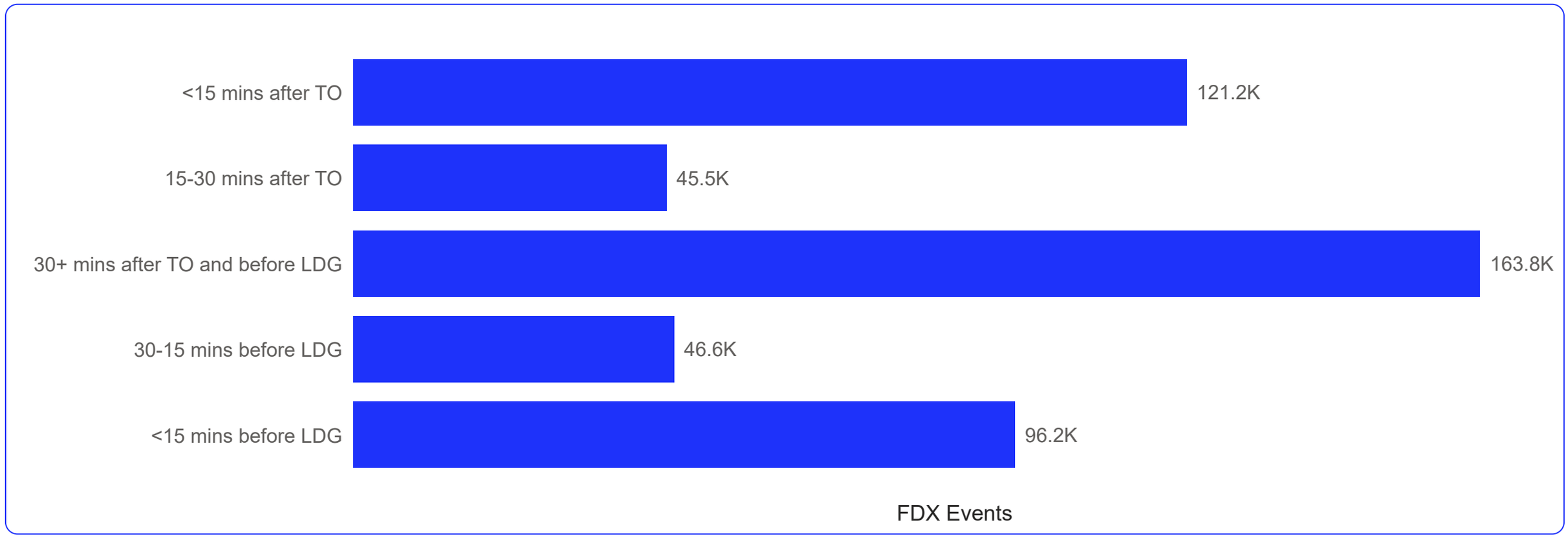


GPS Signal Loss Occurrence Phase

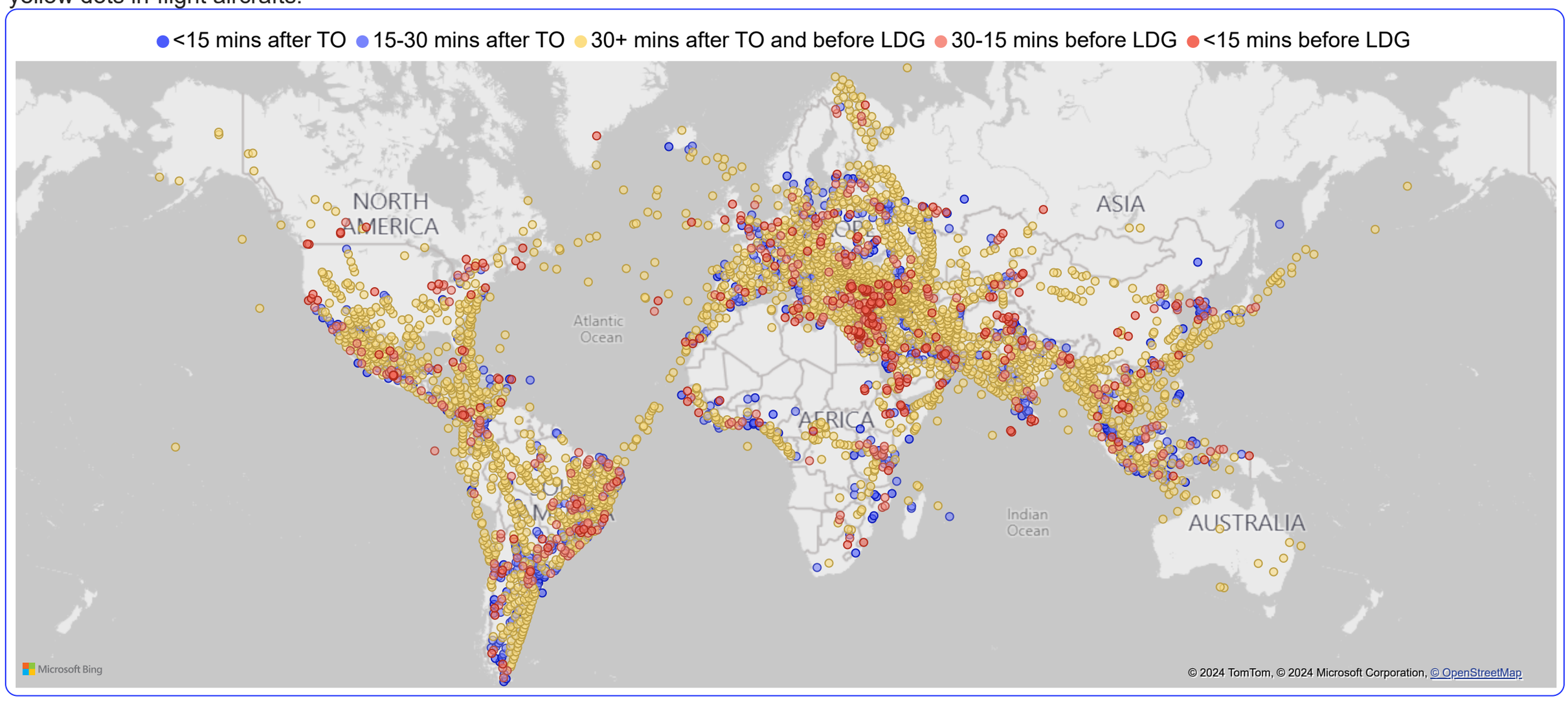
Region:
Global

Period:
2021 Aug - 2023 Dec

In FDX Program when a GPS Signal Loss event triggers an event time information is also recorded. This event time information contains time values of event start and event end moments. Below chart presents the distribution of the GPS Signal Loss events according to their event start time value to see at which flight time the event was first triggered.



Similar to event time, latitude and longitude information are also recorded alongside each triggered event. When flight phase and geographic location of each GPS Signal Loss event combined below map can be obtained. In this map blue dots represent departing aircrafts while red dots arriving and yellow dots in-flight aircrafts.

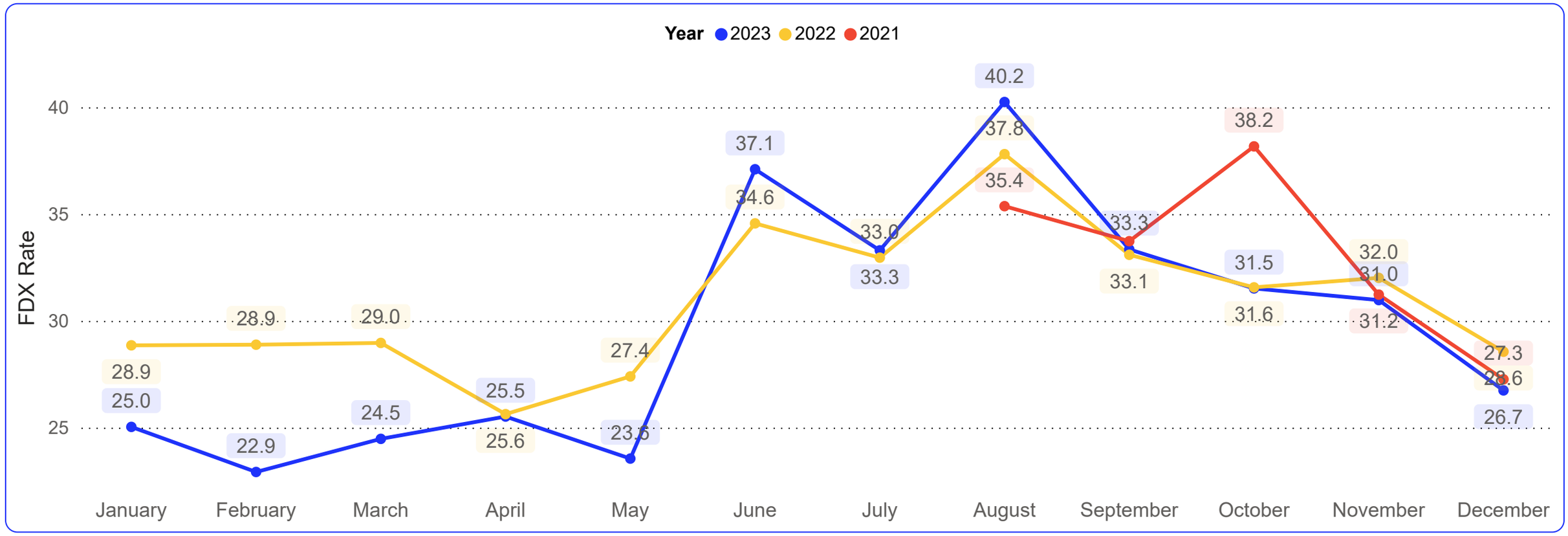


GPS Signal Loss Occurrence Time

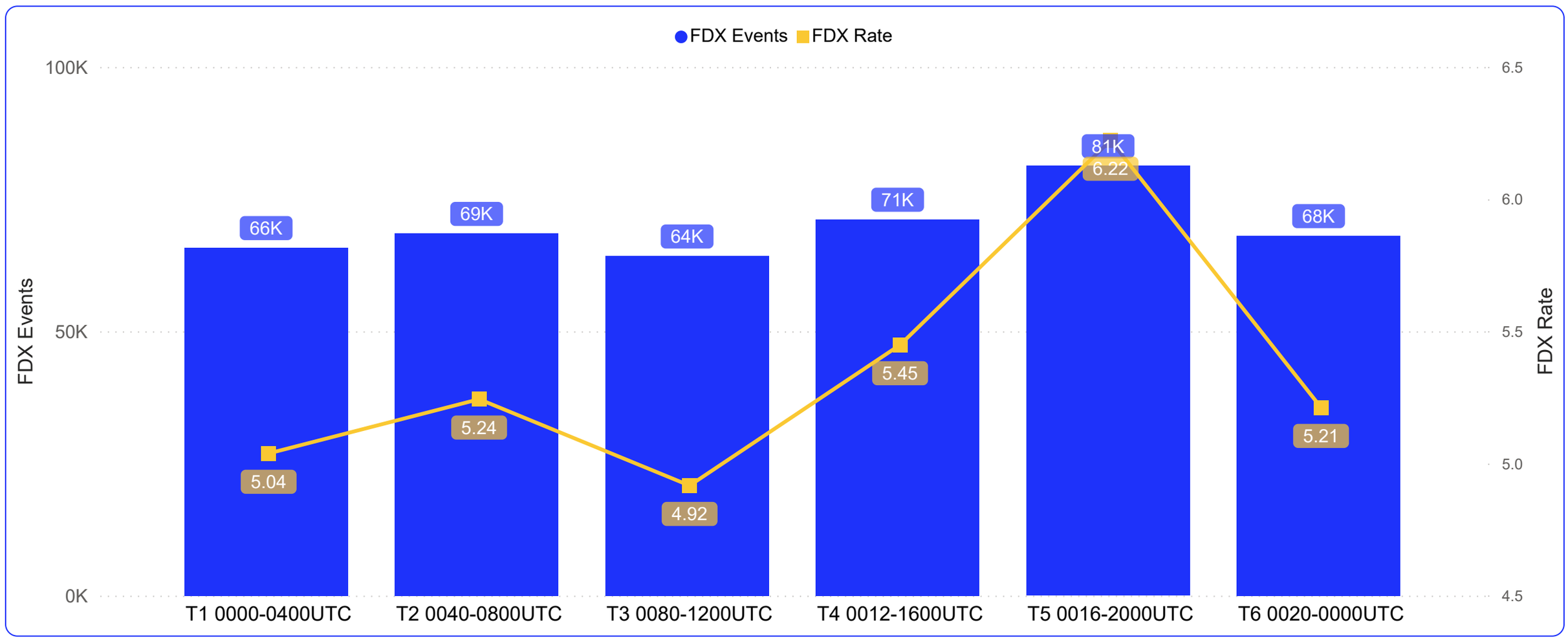
Region: Global

Period: 2021 Aug - 2023 Dec

GPS Signal Loss event time information analyzed in terms of the month of the occurrence. Although the history of the event is not very long to estimate if there is any seasonality effect on the occurrence rate or not, when the rate change per month graph drawn as below continuity of the event rate throughout of the year can be observed.



GPS Signal Loss event time information analyzed in terms of UTC time of the occurrence. Close number of occurrences for each four hours period of the day also indicates the continuity of the GPS Signal Loss event. One important consideration for the readers is that UTC time buckets do not correlate directly with the day or night light conditions in this analysis report.



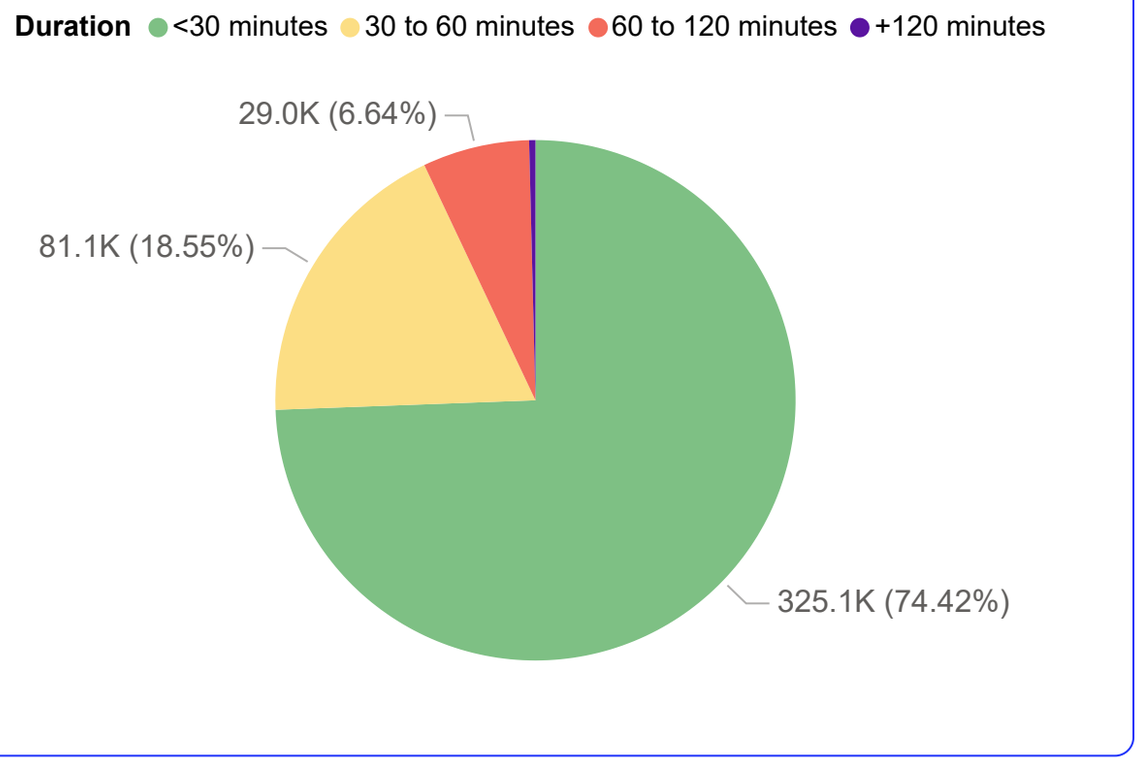
Based on the time trend analysis of the GPS Signal Loss occurrences in FDX Program it can be assumed that the probability of the event is behaving independent from the season of the year or time of the day.

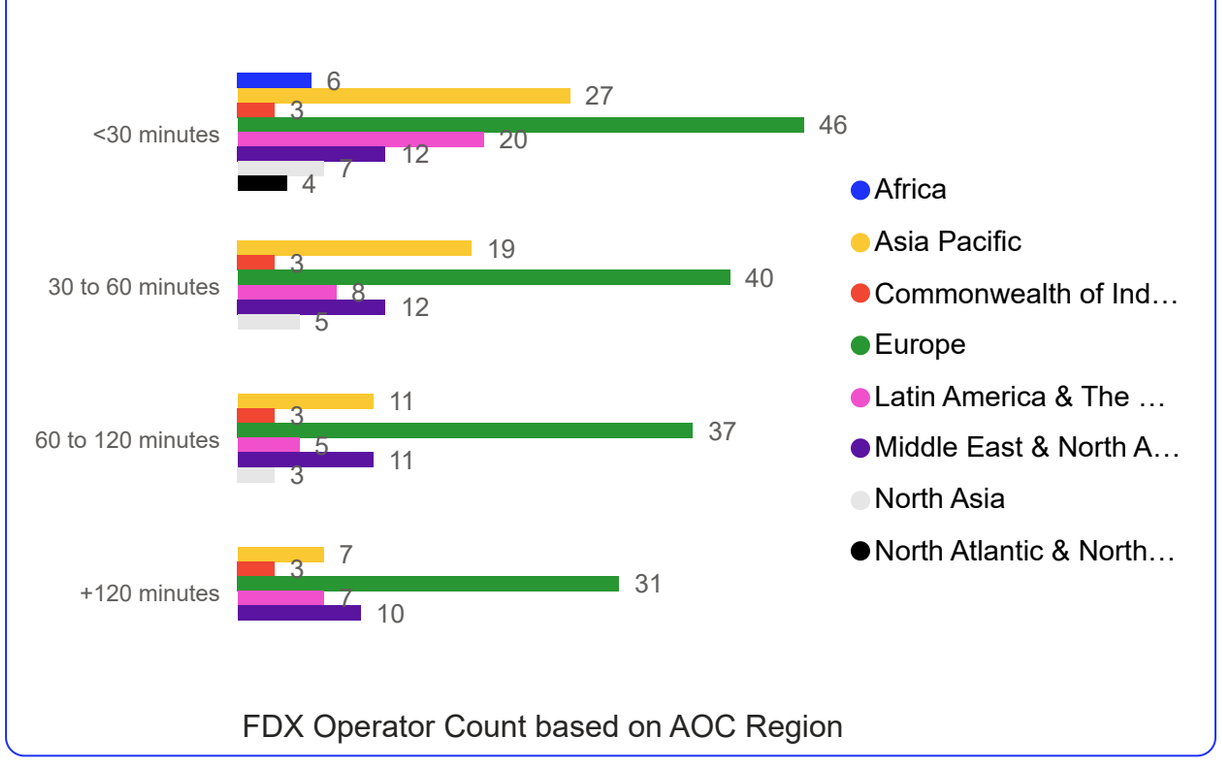
GPS Signal Loss Occurrence Duration

Region: Global

Period: 2021 Aug - 2023 Dec

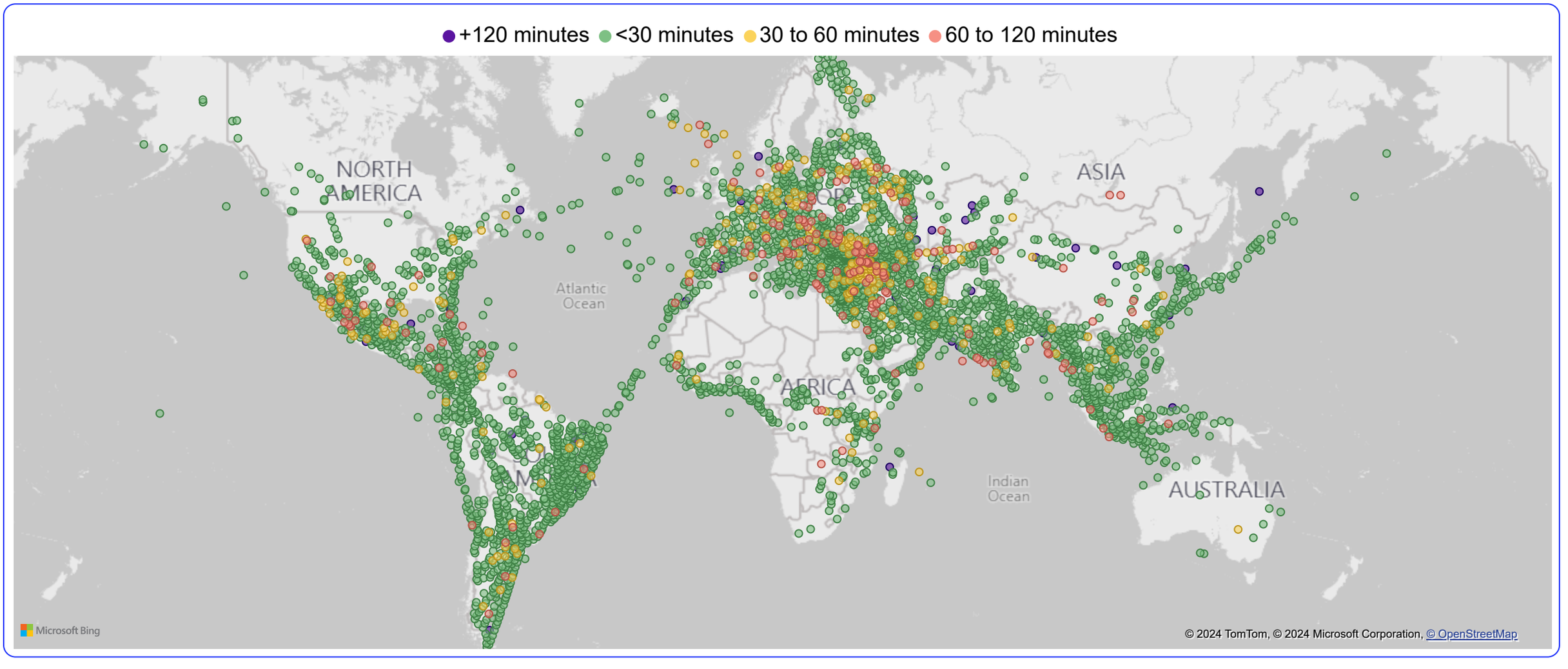
GPS Signal Loss duration is another derived parameter that is used in this analysis report. Event duration obtained from the event start and end times. Duration of event can be treated as the severity value of each occurrence. While interpreting these results the actual flight time duration should be considered carefully. On the other hand, the graph on the right side shows the count of the operator by bins of the duration of the event, sliced by region, this shows how the condition is widespread across all operators.





FDX Operator Count based on AOC Region

Using the event duration bins as a legend below GPS Signal Loss occurrence map can be obtained where each dot represents the starting point of a GPS Signal Loss occurrence on the globe. While interpreting this map it should be considered that duration calculation is based on the event start and end time of each GPS Signal Loss case, and if a flight completed without available GPS Signal on board the actual landing time would be considered as event end time. Also readers should consider that the map visual in PBI might limit the number of data points displayed.



GPS Signal Loss Occurrence Routes

Region: Global

Period: 2021 Aug - 2023 Dec

In FDX Program due to the nature of this occurrence GPS Signal Loss event is assigned to the route pairs. In the route pairs analysis of this report country level route pairs have been used and below table shows country pairs of each occurrence from the highest rate to the lowest. FDX Flights column corresponds the number of flights analyzed in FDX Program within the assigned country pair, similarly FDX Events and FDX Rate values of each country pair can be reviewed in same row. FDX Operator Count is the number of operators affected from a GPS Signal Loss event within the given country route pair.

Country Pairs	FDX Flights	FDX Events	FDX Rate	FDX Operator Count
Romania - United Arab Emirates	1,104	1,073	971.92	5
Turkiye - Iraq	1,302	1,261	968.51	4
Iraq - Turkiye	1,342	1,296	965.72	4
United Arab Emirates - Romania	1,106	1,033	934.00	5
Turkiye - Iran, Islamic Republic of	1,056	948	897.73	4
Turkiye - United Arab Emirates	2,490	2,139	859.04	4
Qatar - Turkiye	2,222	1,760	792.08	3
United Arab Emirates - Turkiye	2,648	2,055	776.06	4
Turkiye - Qatar	2,272	1,760	774.65	3
Lebanon - Turkiye	1,331	1,028	772.35	3
Turkiye - Lebanon	1,314	944	718.42	3
Turkiye - Russian Federation (West of the Urals)1	4,070	2,806	689.43	3
Iran, Islamic Republic of - Turkiye	1,080	721	667.59	4
Russian Federation (West of the Urals)1 - Turkiye	4,139	2,644	638.80	4
Turkiye - Israel	3,384	1,921	567.67	9
Israel - Turkiye	3,355	1,865	555.89	8
Georgia - Turkiye	1,373	726	528.77	3
United Arab Emirates - Italy	1,342	706	526.08	7
Turkiye - Georgia	1,392	687	493.53	3
Saudi Arabia - Turkiye	2,248	1,077	479.09	9
Cyprus - Israel	2,940	1,403	477.21	10
Germany - Israel	1,972	938	475.66	4
Israel - Romania	2,276	1,073	471.44	8
Turkiye - Saudi Arabia	2,241	1,045	466.31	9
Israel - Cyprus	2,922	1,338	457.91	10
Israel - Germany	1,965	899	457.51	5
Romania - Israel	2,285	1,009	441.58	7
Italy - Israel	3,732	1,625	435.42	7
Israel - Hungary	1,929	811	420.43	6
Turkiye - Turkiye	85,955	35,551	413.60	6
Italy - United Arab Emirates	1,403	562	400.57	6
Bulgaria - Israel	1,331	527	395.94	7
Turkiye - Jordan	1,921	760	395.63	4
Jordan - Turkiye	1,909	743	389.21	4

GPS Signal Loss Occurrence Time

Region: Global

Period: 2021 Aug - 2023 Dec

Below matrix can be obtained when the UTC occurrence time of the GPS Signal Loss events combined with the FDX Events values of each country route pair. In this matrix TOP 35 country route pairs listed from the highest to the lowest FDX event count

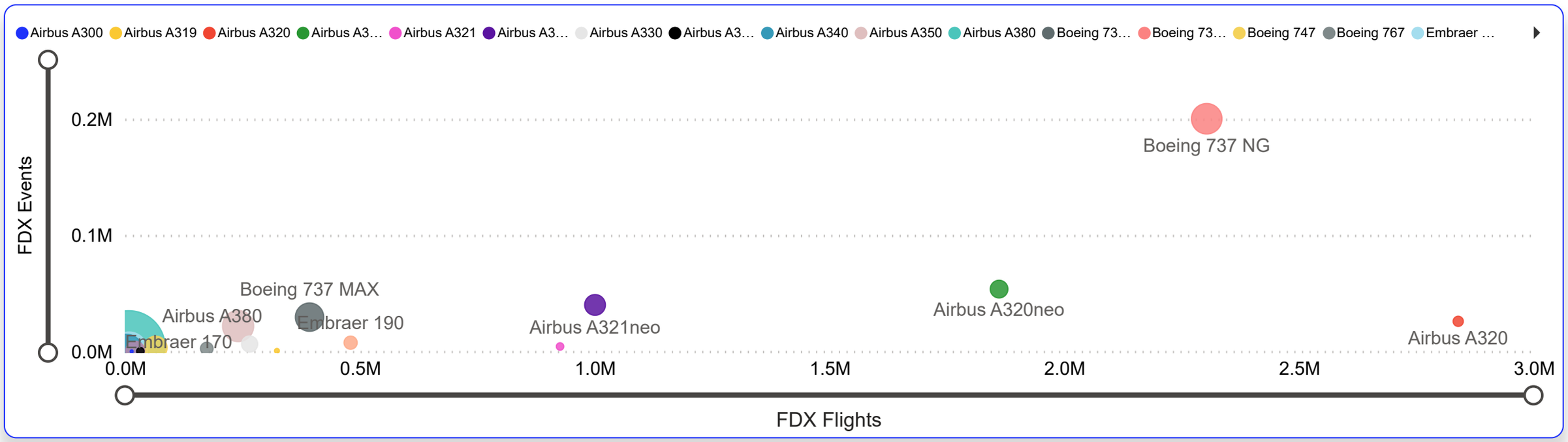
TOP 35 Country Pairs per FDX Events of GPS Signal Loss

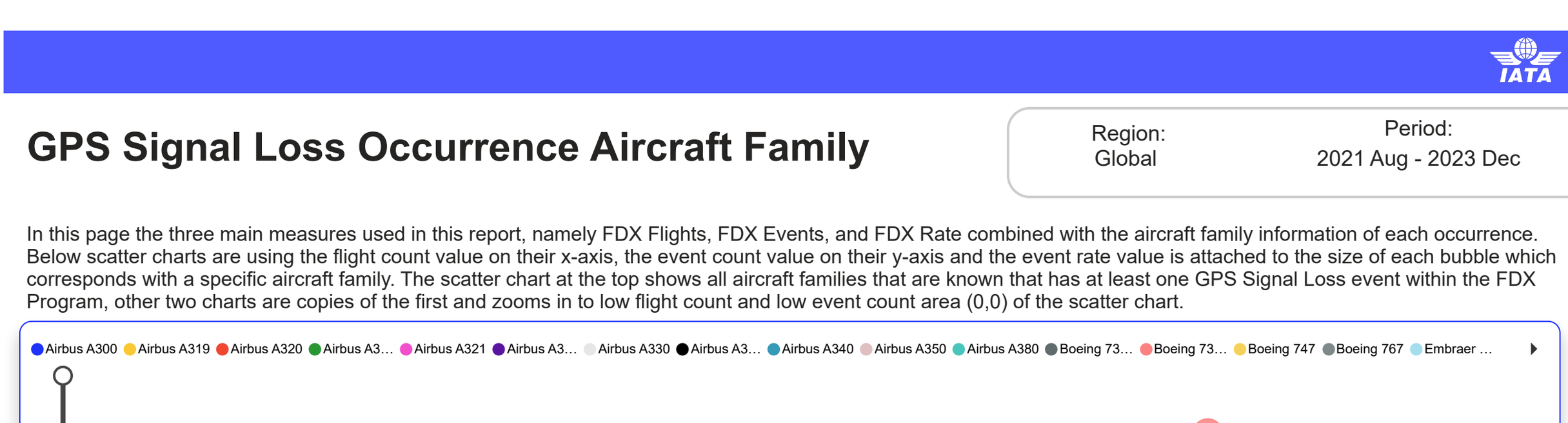
Country Pairs	T1 0000-0400UTC	T2 0040-0800UTC	T3 0080-1200UTC	T4 0012-1600UTC	T5 0016-2000UTC	T6 0020-0000UTC	Total
Turkiye - Turkiye	2,757	10,033	5,645	4,691	9,532	4,035	**35,551**
Mexico - Mexico	7,209	1,713	963	4,888	3,763	3,251	**21,759**
Egypt - Egypt	192	2,111	1,143	1,042	1,134	1,009	**6,610**
Turkiye - Germany	1,764	860	571	1,372	203	469	**5,120**
Germany - Turkiye	267	311	708	547	472	2,077	**4,257**
United States of America - Mexico	703	327	626	589	617	931	**3,780**
Brazil - Brazil	947	65	419	1,052	350	712	**3,535**
United Arab Emirates - Russian Federation (West of the Urals)1	334	360	1,041	145	639	1,131	**3,387**
Russian Federation (West of the Urals)1 - United Arab Emirates	848	364	458	907	85	848	**3,146**
Turkiye - Russian Federation (West of the Urals)1	289	286	481	188	528	1,394	**2,806**
Turkiye - Cyprus	113	575	506	544	704	239	**2,658**
Russian Federation (West of the Urals)1 - Turkiye	1,094	202	113	705	143	664	**2,644**
Saudi Arabia - Egypt	440	538	267	402	336	683	**2,639**
Cyprus - Turkiye	210	510	458	543	615	137	**2,420**
Egypt - Saudi Arabia	179	346	172	407	484	593	**2,165**
Turkiye - United Arab Emirates	261	11	30	363	565	1,193	**2,139**
United Arab Emirates - Turkiye	763	703	350	107	244	205	**2,055**
Qatar - United Kingdom	822	752	256	172	145	2	**1,929**
Turkiye - Israel	101	345	499	226	220	583	**1,921**
Israel - Turkiye	258	548	613	284	175	37	**1,865**
Greece - Israel	38	152	538	422	285	472	**1,862**
Qatar - Turkiye	400	451	470	399	70	18	**1,760**
Turkiye - Qatar	21	57	343	493	641	230	**1,760**
United Kingdom - Qatar	78	0	291	684	716	82	**1,735**
Panama - Mexico	421	369	4	122	578	261	**1,701**
Italy - Israel	356	113	257	346	308	277	**1,625**
Mexico - United States of America	515	27	11	525	234	261	**1,572**
Cyprus - Israel	70	300	195	194	472	192	**1,403**
Israel - Greece	118	381	332	201	307	44	**1,359**
Israel - Italy	245	284	158	201	289	232	**1,353**
Israel - Cyprus	15	335	220	334	364	82	**1,338**
Iraq - Turkiye	908	93	165	145	45	32	**1,296**
Turkiye - Iraq	36	125	194	106	7	864	**1,261**
Qatar - Germany	452	168	422	92	2	3	**1,087**
Saudi Arabia - Turkiye	499	207	47	230	92	40	**1,077**

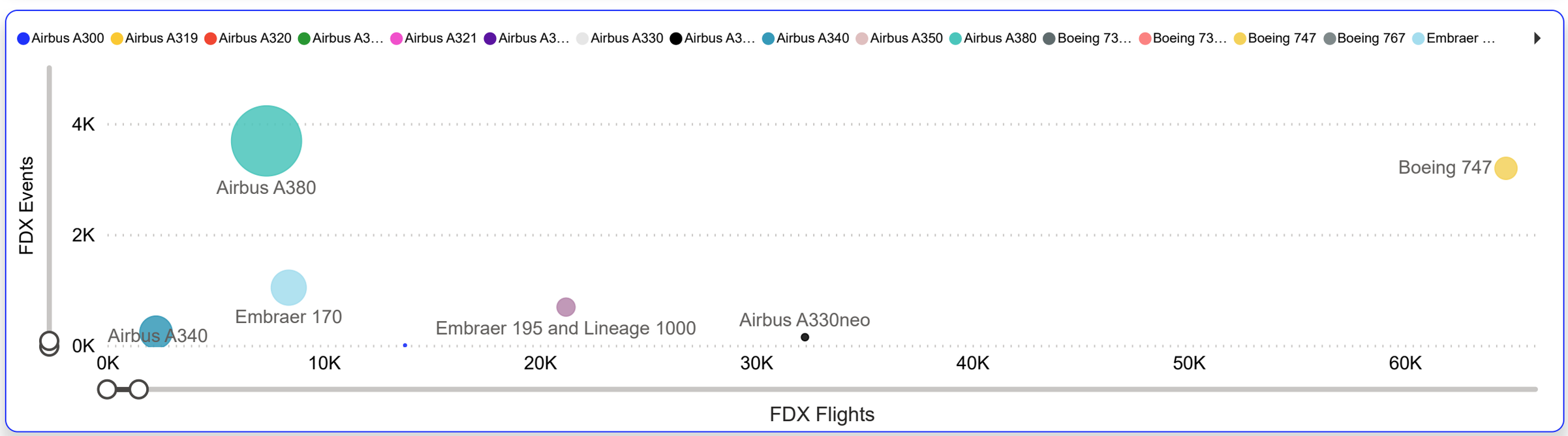
GPS Signal Loss Occurrence Aircraft Family

Region:	Period:
Global	2021 Aug - 2023 Dec

In this page the three main measures used in this report, namely FDX Flights, FDX Events, and FDX Rate combined with the aircraft family information of each occurrence. Below scatter charts are using the flight count value on their x-axis, the event count value on their y-axis and the event rate value is attached to the size of each bubble which corresponds with a specific aircraft family. The scatter chart at the top shows all aircraft families that are known that has at least one GPS Signal Loss event within the FDX Program, other two charts are copies of the first and zooms in to low flight count and low event count area (0,0) of the scatter chart.







GPS Signal Loss

Focus on ASPAC region

2021 Aug - 2023 Dec

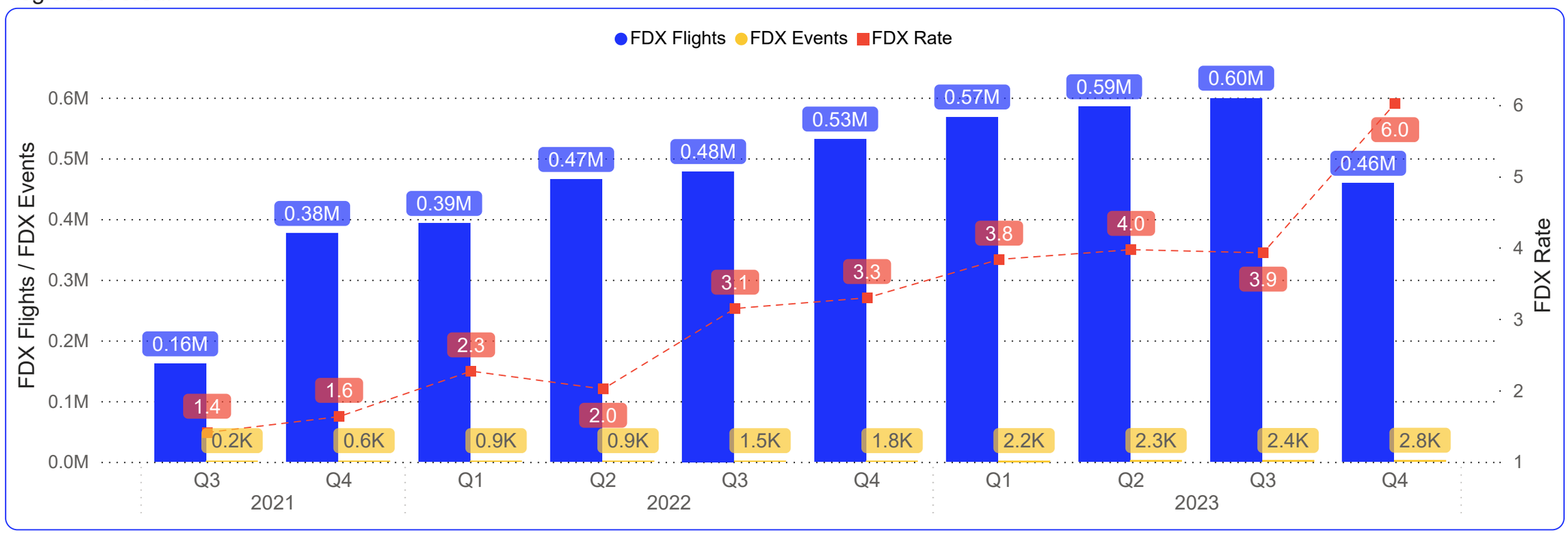
Produced in February 2024

Focus on ASPAC GPS Signal Loss Occurrence Rate

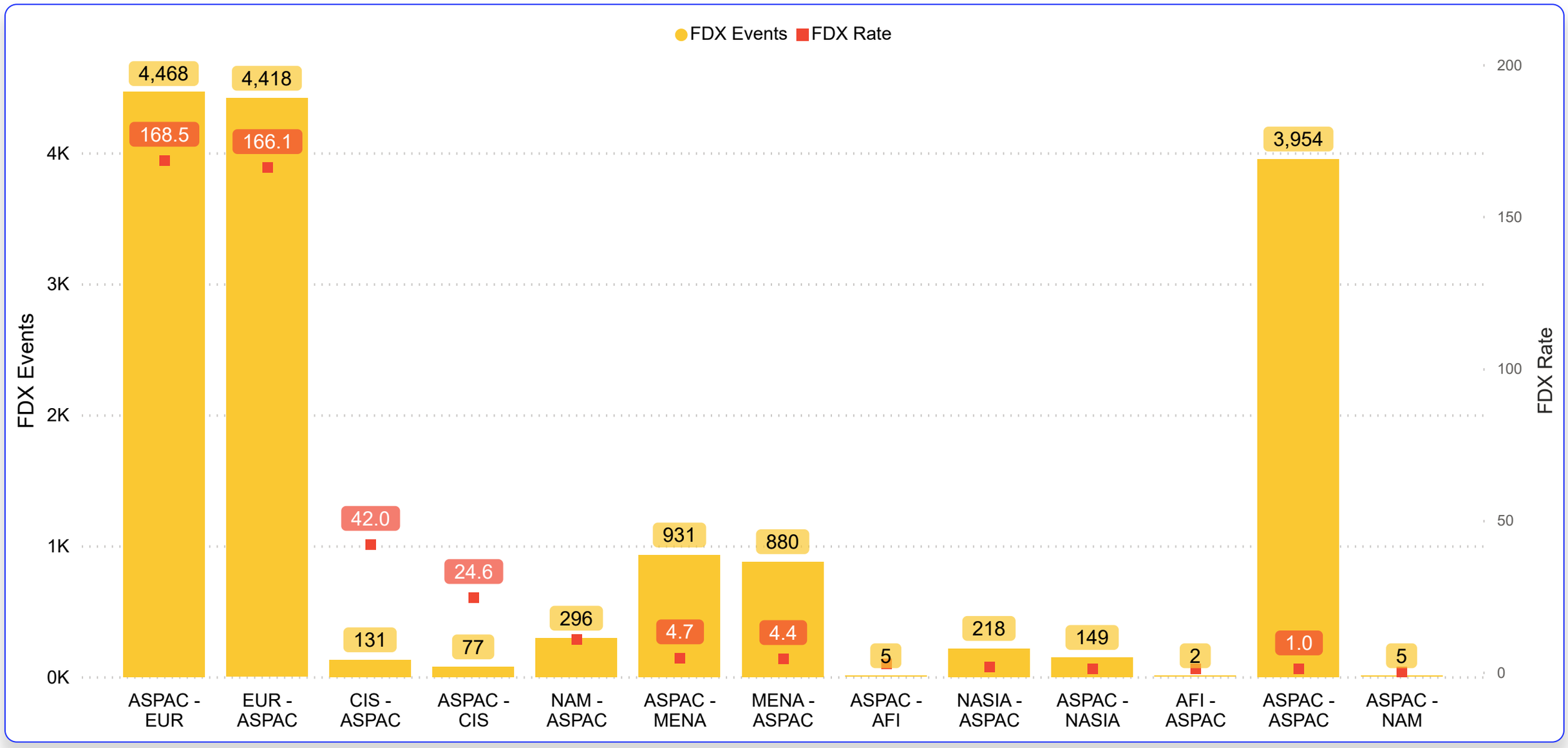
Region: ASPAC

Period: 2021 Aug - 2023 Dec

Below chart presents quarterly rate distribution of the GPS Signal Loss events comparative to the total number of flights analyzed and number of events triggered within the FDX Program. This page focuses on ASPAC traffic only, flights either departed from or arrived to an airport within ASPAC region covered.



The following chart presents the count and rate of the GPS Signal Loss event within the most affected ASPAC traffic route pairs by FDX Rate.

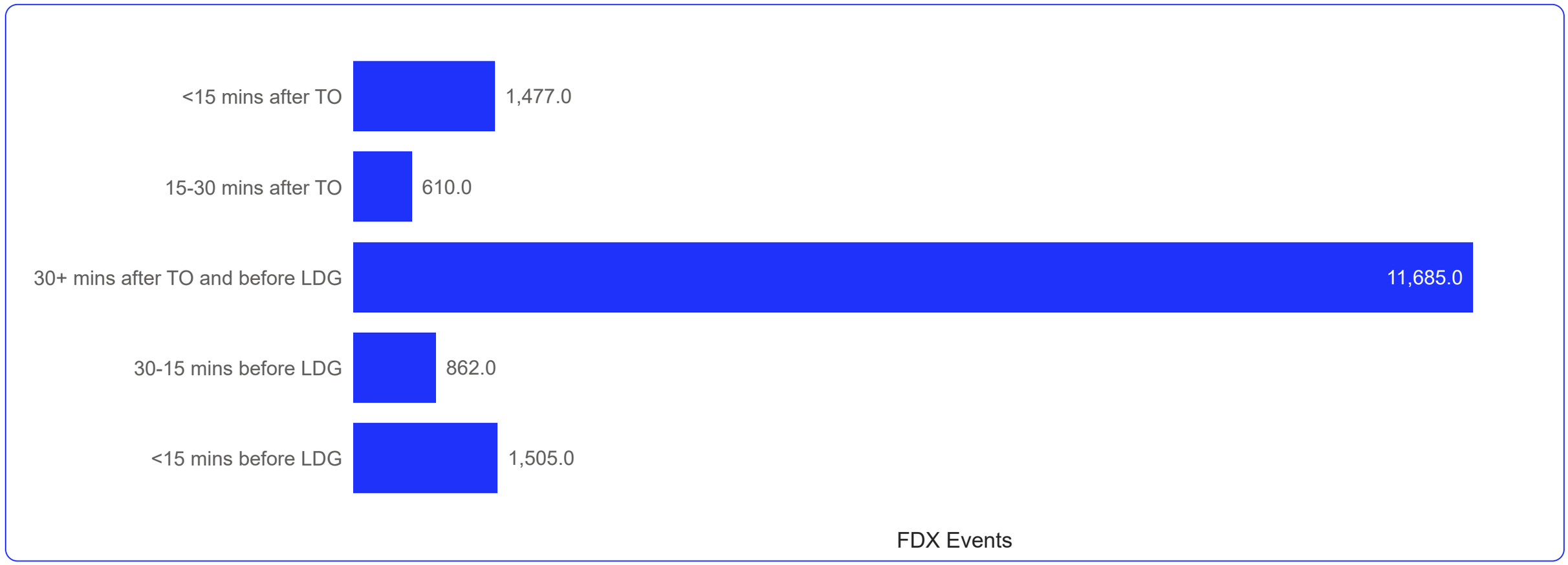


Focus on ASPAC GPS Signal Loss Occurrence Phase

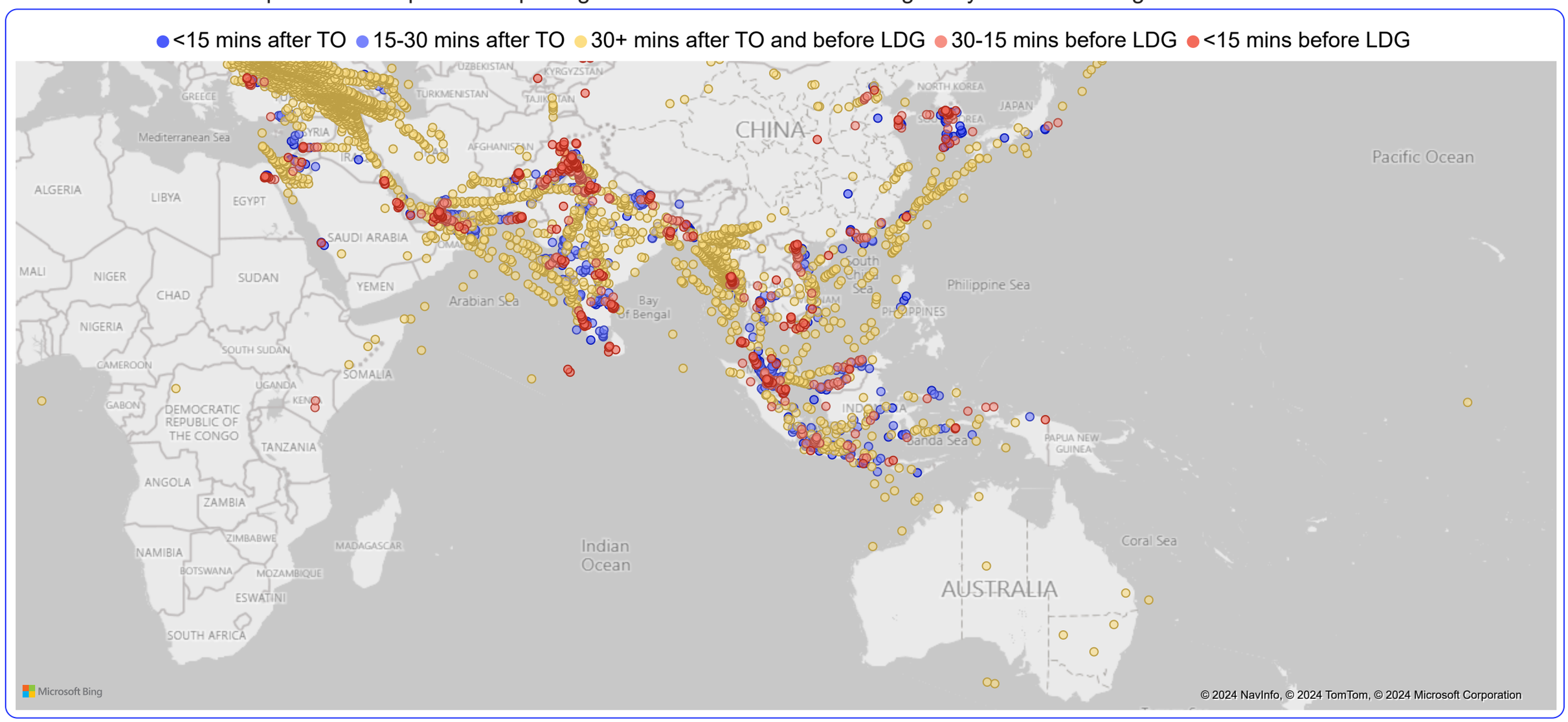
Region: ASPAC

Period: 2021 Aug - 2023 Dec

Below chart presents the distribution of the GPS Signal Loss events according to their event start time value to see at which flight time the event was first triggered. This page focuses on ASPAC traffic only, flights either departed from or arrived to an airport within ASPAC region covered.



ASPAC traffic related GPS Signal Lost events show below distribution when the event trigger time distributed on map with relationship to flight start-end time. In this map blue dots represent departing aircrafts while red dots arriving and yellow dots in-flight aircrafts.

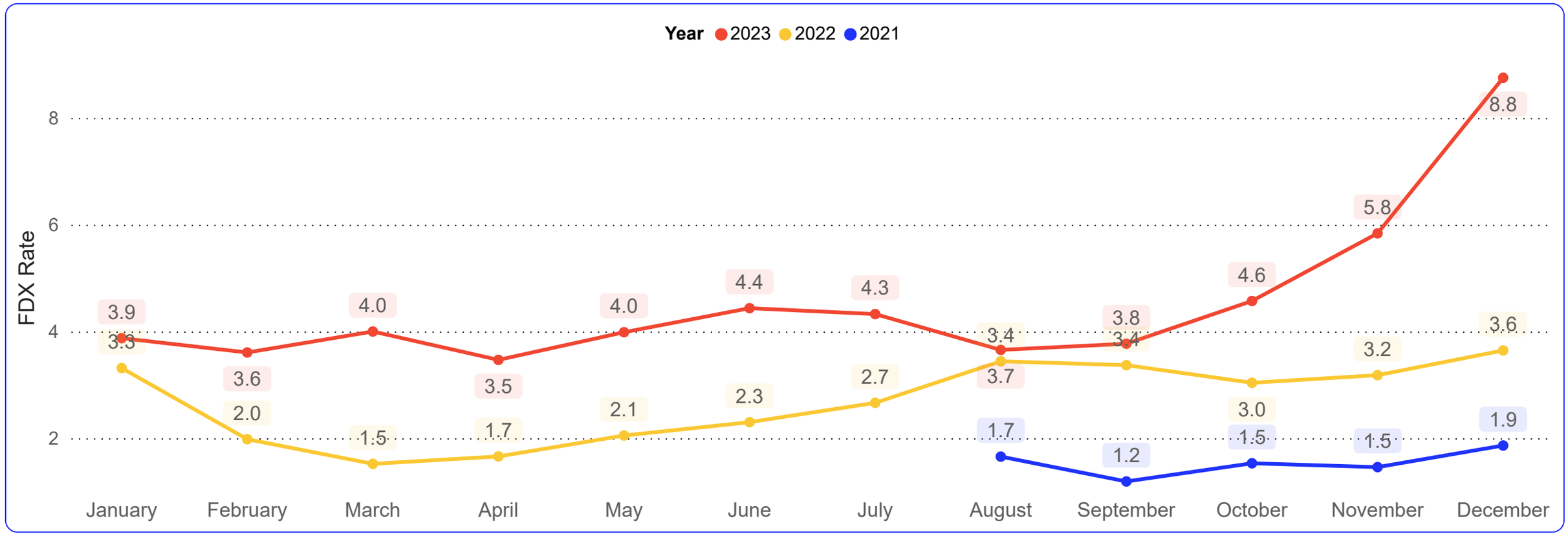


Focus on ASPAC GPS Signal Loss Occurrence Time

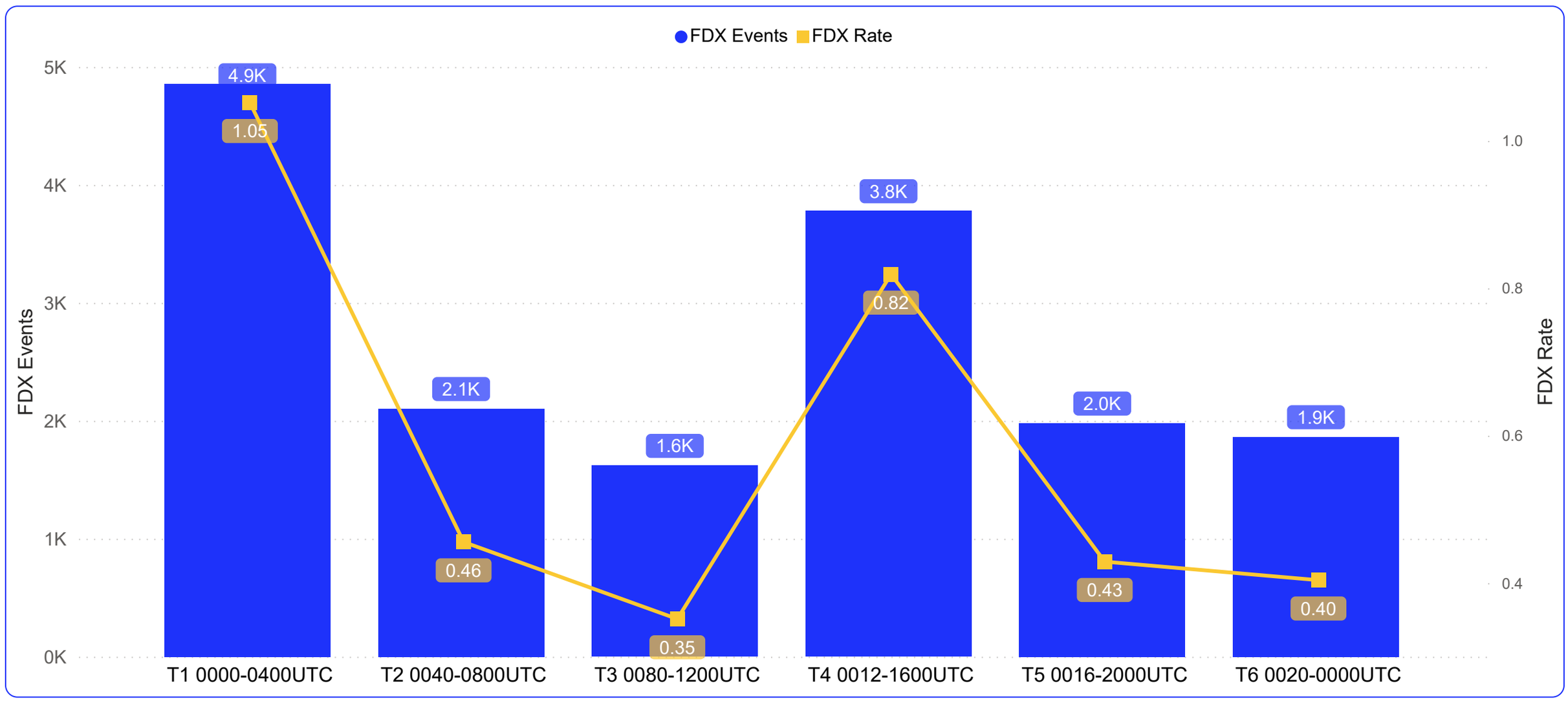
Region: ASPAC

Period: 2021 Aug - 2023 Dec

This page focuses on ASPAC traffic only, flights either departed from or arrived to an airport within ASPAC region covered. When the rate change per month graph drawn as below continuity of the event rate throughout of the years can be observed. Trend increase in ASPAC traffic can also be identified.



ASPAC traffic shows similar pattern to Global trends in terms of occurrence UTC time. Close number of occurrences for each four hours period of the day also indicates the continuity of the GPS Signal Loss event. One important consideration for the readers is that UTC time buckets do not correlate directly with the day or night light conditions in this analysis report.

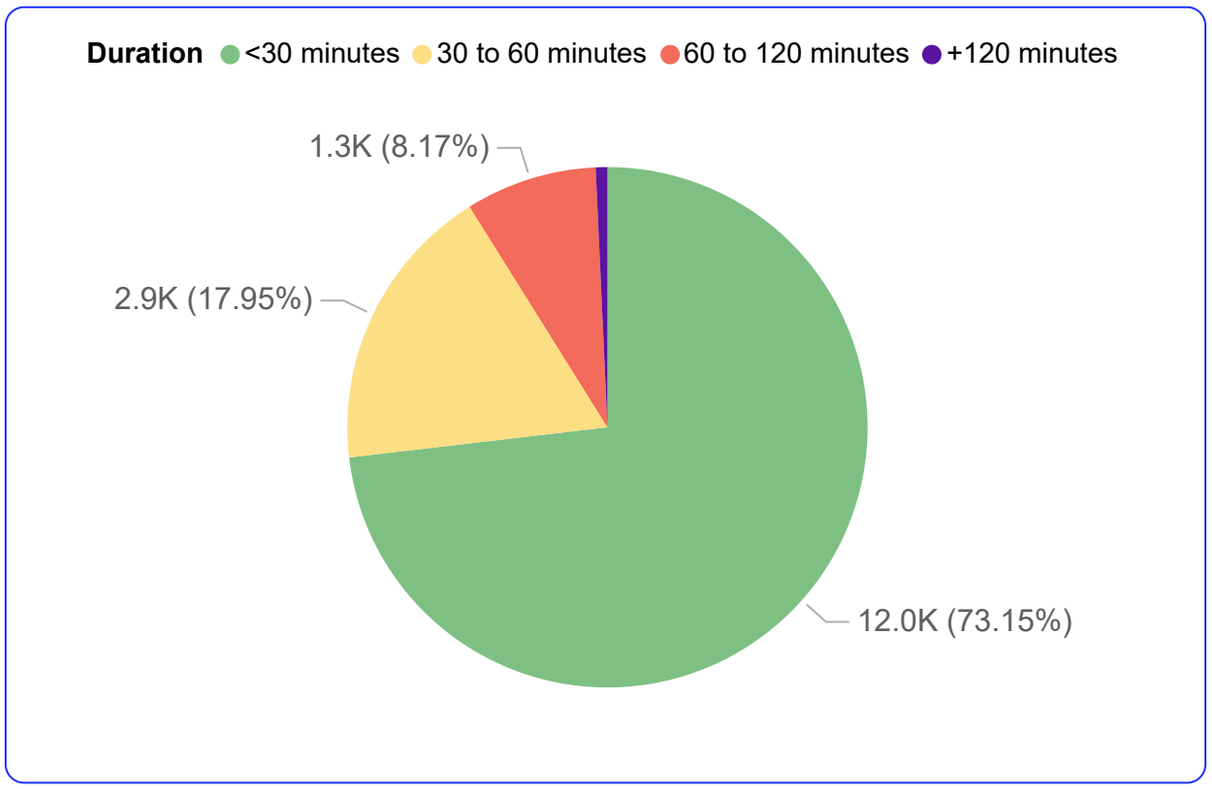


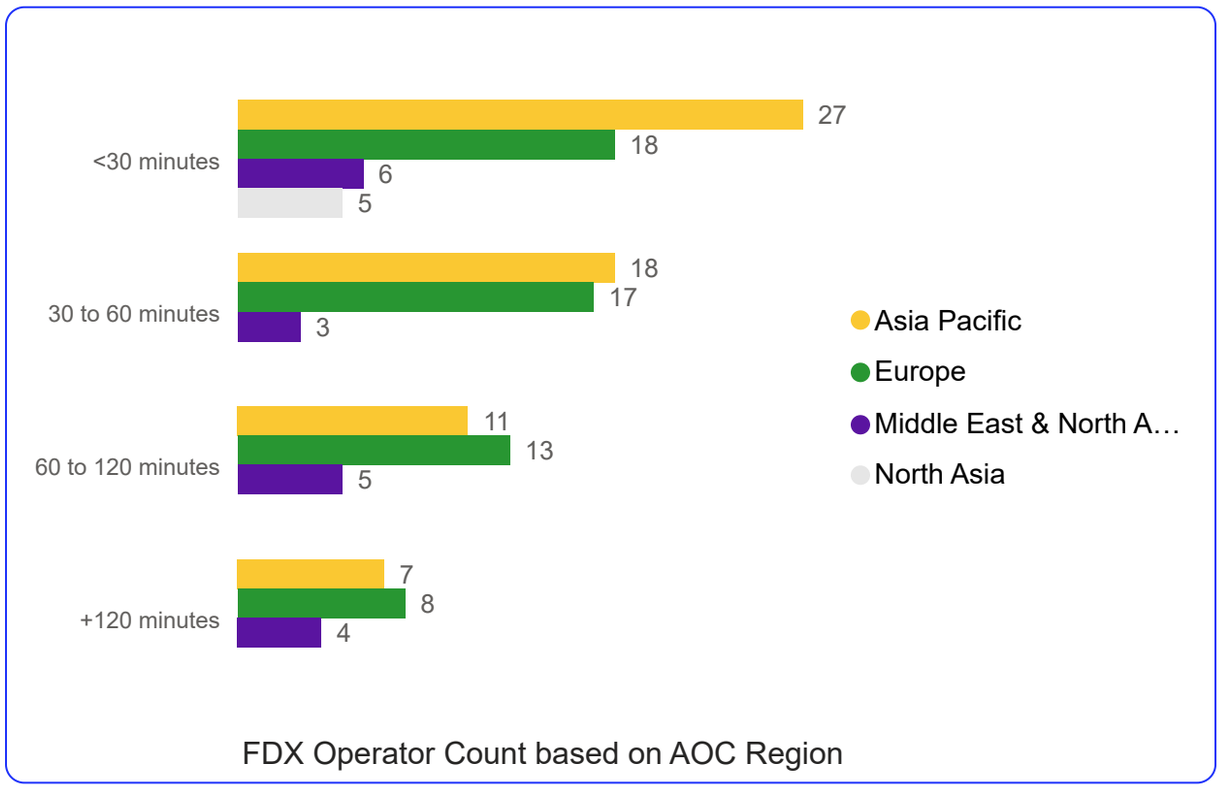
Focus on ASPAC GPS Signal Loss Occurrence Duration

Region: ASPAC

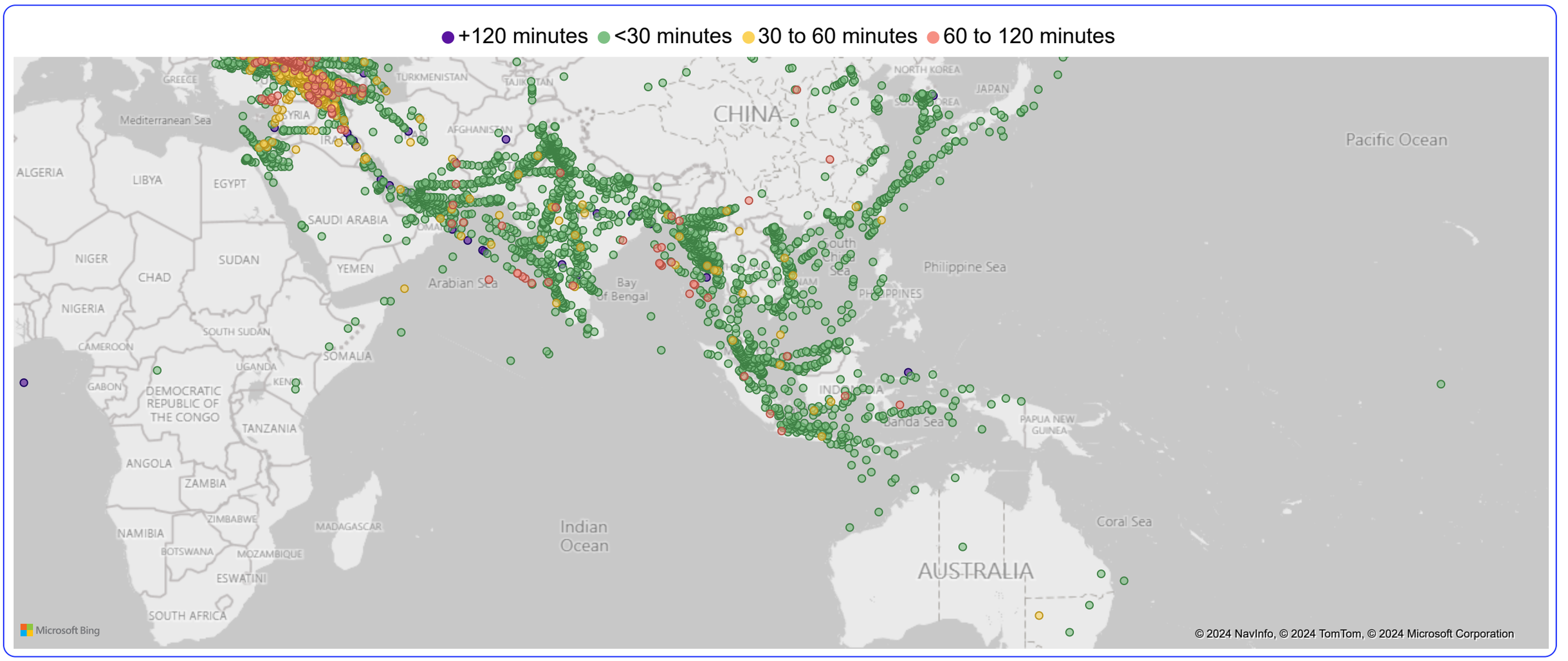
Period: 2021 Aug - 2023 Dec

ASPAC traffic shows below distribution in terms of GPS Signal Loss duration. This value of the each triggered event can be considered as the severity of each occurrence. While interpreting these results the actual flight time duration should be considered carefully. On the other hand, the graph on the right side shows the count of the operator by bins of the duration of the event, sliced by region, this shows how the condition is widespread across all operators operating from/to ASPAC region.





Using the event duration bins as a legend below GPS Signal Loss occurrence map can be obtained where each dot represents the starting point of a GPS Signal Loss occurrence on the globe. While interpreting this map it should be considered that duration calculation is based on the event start and end time of each GPS Signal Loss case, and if a flight completed without available GPS Signal on board the actual landing time would be considered as event end time. Also readers should consider that the map visual in PBI might limit the number of data points displayed.



Focus on ASPAC GPS Signal Loss Occurrence Routes

Region: ASPAC

Period: 2021 Aug - 2023 Dec

While focusing ASPAC traffic only, in the route pairs analysis page of this report, country level route pairs have been used and below table built to present country pairs of each occurrence from the highest rate to the lowest. FDX Flights column corresponds the number of flights analyzed in FDX Program within the assigned country pair, similarly FDX Events and FDX Rate values of each country pair can be reviewed in same row. FDX Operator Count is the number of operators affected from a GPS Signal Loss event within the given country route pair.

Country Pairs	FDX Flights	FDX Events	FDX Rate	FDX Operator Count
Bangladesh - Malaysia	2,273	389	171.14	4
Malaysia - Bangladesh	2,264	339	149.73	4
India - United Kingdom	4,316	330	76.46	4
United Kingdom - India	4,136	269	65.04	3
Hong Kong (SAR), China - India	4,906	111	22.63	3
India - Malaysia	7,135	102	14.30	4
Malaysia - India	7,142	84	11.76	4
Nepal - Malaysia	2,423	26	10.73	3
Malaysia - Nepal	2,428	21	8.65	3
India - Hong Kong (SAR), China	4,772	31	6.50	4
India - Thailand	6,581	39	5.93	6
Thailand - India	6,621	34	5.14	5
India - Saudi Arabia	11,548	52	4.50	4
United Arab Emirates - India	44,855	197	4.39	5
Saudi Arabia - Pakistan	5,147	22	4.27	3
Malaysia - Viet Nam	3,788	16	4.22	3
Korea, Republic of - China, People's Republic of	3,159	12	3.80	4
India - United Arab Emirates	46,436	176	3.79	6
Singapore - Malaysia	15,610	42	2.69	3
Saudi Arabia - India	11,351	22	1.94	3
Indonesia - Singapore	11,558	21	1.82	3
Thailand - Malaysia	5,393	9	1.67	3
Malaysia - Singapore	15,255	25	1.64	3
Hong Kong (SAR), China - Korea, Republic of	4,229	6	1.42	4
Singapore - Viet Nam	7,217	10	1.39	3
Korea, Republic of - Hong Kong (SAR), China	4,553	6	1.32	3
Japan - Hong Kong (SAR), China	20,110	25	1.24	3
Chinese Taipei - Japan	7,109	7	0.98	3
Korea, Republic of - Korea, Republic of	207,872	171	0.82	4
Japan - Korea, Republic of	24,830	18	0.72	4
Japan - Chinese Taipei	7,672	5	0.65	4
Korea, Republic of - Viet Nam	13,604	8	0.59	3
Hong Kong (SAR), China - Japan	20,763	12	0.58	4
Hong Kong (SAR), China - Thailand	8,960	5	0.56	3
India - Qatar	23,032	12	0.52	3

Focus on ASPAC GPS Signal Loss Occurrence Time

Region: ASPAC

Period: 2021 Aug - 2023 Dec

When the matrix below adapted to ASPAC traffic only, most affected country route pairs based on number of triggered events can be reviewed.

Country Pairs per FDX Events of GPS Signal Loss

Country Pairs	T1 0000-0400UTC	T2 0040-0800UTC	T3 0080-1200UTC	T4 0012-1600UTC	T5 0016-2000UTC	T6 0020-0000UTC	Total
Bangladesh - Malaysia	1	62	110	48	92	101	**389**
Malaysia - Bangladesh	80	81	1	82	88	37	**339**
India - United Kingdom	32	22	162	132	10	0	**330**
United Kingdom - India	15	1	0	39	13	207	**269**
India - India	59	53	56	65	20	3	**256**
United Arab Emirates - India	64	11	22	15	33	73	**197**
India - United Arab Emirates	76	37	22	19	19	26	**176**
Korea, Republic of - Korea, Republic of	52	52	39	13	0	16	**171**
Indonesia - Indonesia	44	25	34	8	9	29	**147**
Hong Kong (SAR), China - India	14	41	18	17	20	4	**111**
India - Malaysia	0	7	8	5	59	26	**102**
Malaysia - India	2	7	1	34	45	0	**84**
India - Saudi Arabia	2	17	14	6	3	11	**52**
Singapore - Malaysia	13	17	4	0	2	6	**42**
India - Thailand	1	9	1	13	5	10	**39**
Thailand - India	0	15	5	13	1	0	**34**
India - Hong Kong (SAR), China	0	1	3	4	7	17	**31**
Nepal - Malaysia	0	3	6	2	10	6	**26**
Japan - Hong Kong (SAR), China	2	11	9	3	0	0	**25**
Malaysia - Singapore	8	9	4	3	1	0	**25**
Saudi Arabia - India	0	10	10	1	0	1	**22**
Saudi Arabia - Pakistan	5	0	0	2	1	14	**22**
Indonesia - Singapore	5	5	4	3	0	4	**21**
Malaysia - Nepal	2	6	0	9	1	3	**21**
Japan - Korea, Republic of	5	9	4	0	0	0	**18**
Malaysia - Viet Nam	1	10	4	1	0	0	**16**
Hong Kong (SAR), China - Japan	4	6	1	0	0	1	**12**
India - Qatar	1	1	0	1	1	8	**12**
Korea, Republic of - China, People's Republic of	6	4	1	0	1	0	**12**
Singapore - Viet Nam	4	1	5	0	0	0	**10**
Thailand - Malaysia	0	4	4	2	0	0	**9**
Korea, Republic of - Viet Nam	4	2	0	1	1	0	**8**
Chinese Taipei - Japan	3	0	2	0	0	2	**7**
Hong Kong (SAR), China - Korea, Republic of	3	2	0	0	0	1	**6**
Korea, Republic of - Hong Kong (SAR), China	0	2	3	1	0	0	**6**
Hong Kong (SAR), China - Thailand	3	2	0	0	0	0	**5**

Focus on ASPAC FIRs

Region: ASPAC

Period: 2021 Aug - 2023 Dec

Focusing on ASPAC traffic only allows to review the FIR - GPS Signal Loss relationship as well. Readers should pay attention that below numbers are absolute FDX Events counts with no normalization.

TOP15 FIR per event count per year

FIR	2021	2022	2023	Total
VYYF	2	378	3483	**3863**
VIDF	61	171	758	**990**
OPLR	78	116	638	**832**
WMFC	12	169	204	**385**
RKRR	11	103	136	**250**
OPKR	33	75	141	**249**
VGFR	4	197	16	**217**
VABF	26	66	124	**216**
VOMF	26	64	101	**191**
VVHN	2	72	73	**147**
WSJC	8	106	20	**134**
WAAF	7	57	67	**131**
VECF	1	43	85	**129**
WIIF	7	48	27	**82**
RJJJ	21	17	40	**78**
Total	**299**	**1682**	**5913**	**7894**

TOP15 FIR per event count per flight phase

FIR	<15 mins after TO	15-30 mins after TO	30+ mins after TO and before LDG	30-15 mins before LDG	<15 mins before LDG	Total
VYYF	173	17	3198	246	229	**3863**
VIDF	249	156	188	164	233	**990**
OPLR	265	31	120	133	283	**832**
WMFC	141	30	11	59	144	**385**
RKRR	96	4	2	18	130	**250**
OPKR	56	31	93	20	49	**249**
VGFR	186		4	10	17	**217**
VABF	15	29	147	18	7	**216**
VOMF	37	33	71	12	38	**191**
VVHN	43	6	10	13	75	**147**
WSJC	75	5	38	4	12	**134**
WAAF	21	30	56	14	10	**131**
VECF	2	22	88	8	9	**129**
WIIF	8	21	33	17	3	**82**
RJJJ	3	1	71	3		**78**
Total	**1370**	**416**	**4130**	**739**	**1239**	**7894**

TOP15 ASPAC FIRs per event count and per UTC time buckets

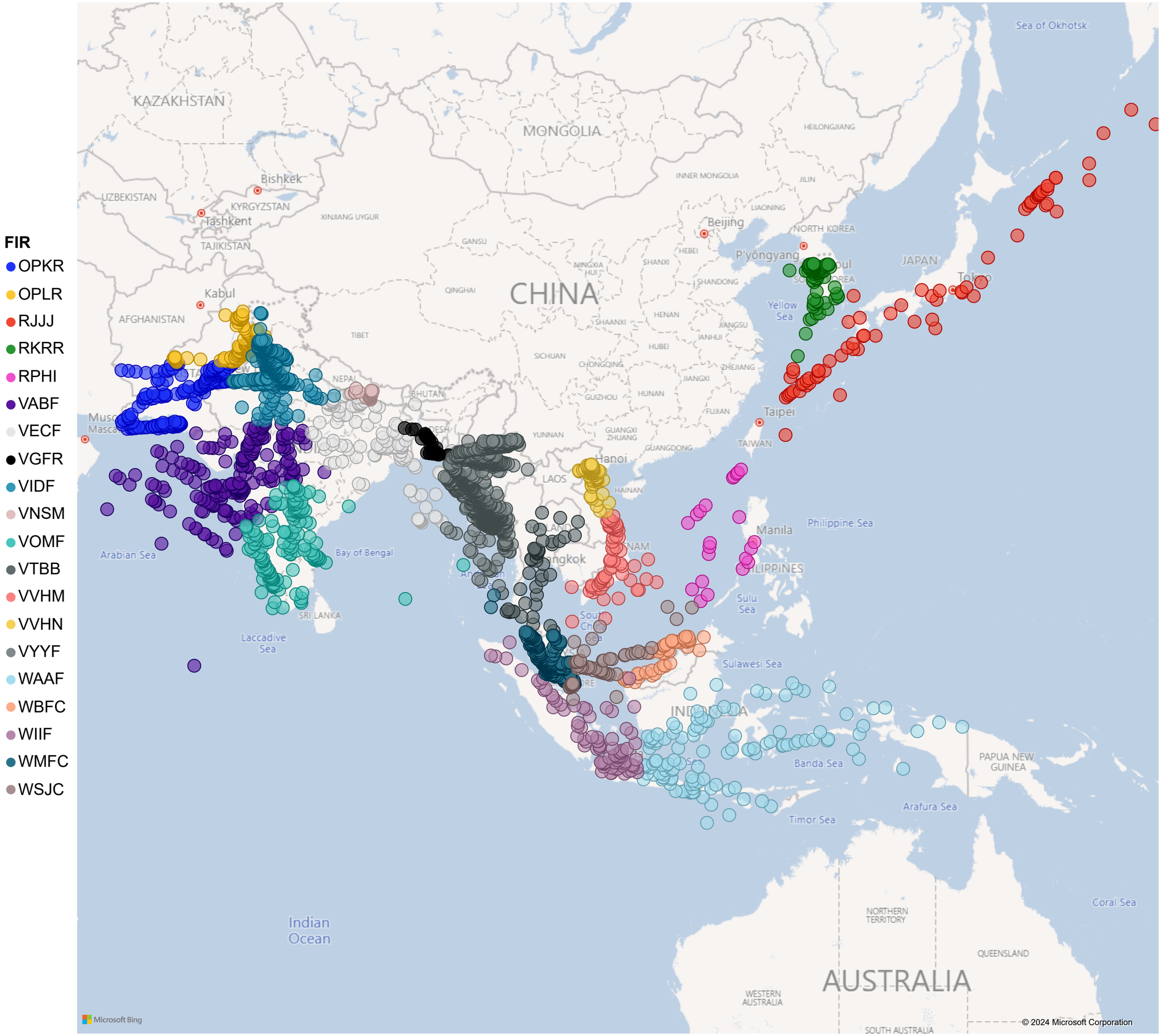
FIR	T1 0000-0400UTC	T2 0040-0800UTC	T3 0080-1200UTC	T4 0012-1600UTC	T5 0016-2000UTC	T6 0020-0000UTC	Total
VYYF	692	767	508	745	628	523	**3863**
VIDF	87	90	72	242	361	138	**990**
OPLR	175	84	50	87	97	339	**832**
WMFC	87	118	92	56	6	26	**385**
RKRR	75	82	59	16		18	**250**
OPKR	40	61	43	22	47	36	**249**
VGFR	50	59	50	54	3	1	**217**
VABF	39	50	28	40	20	39	**216**
VOMF	57	33	29	25	7	40	**191**
VVHN	29	48	37	26	6	1	**147**
WSJC	40	26	36	11	3	18	**134**
WAAF	45	26	20	7	7	26	**131**
VECF	26	20	22	18	30	13	**129**
WIIF	17	14	26	12	3	10	**82**
RJJJ	15	33	17	6	2	5	**78**
Total	**1474**	**1511**	**1089**	**1367**	**1220**	**1233**	**7894**

Focus on ASPAC FIRs - Map View

Region:
ASPAC

Period:
2021 Aug - 2023 Dec

Position of GPS Signal Loss Occurrences in TOP 20 FIR

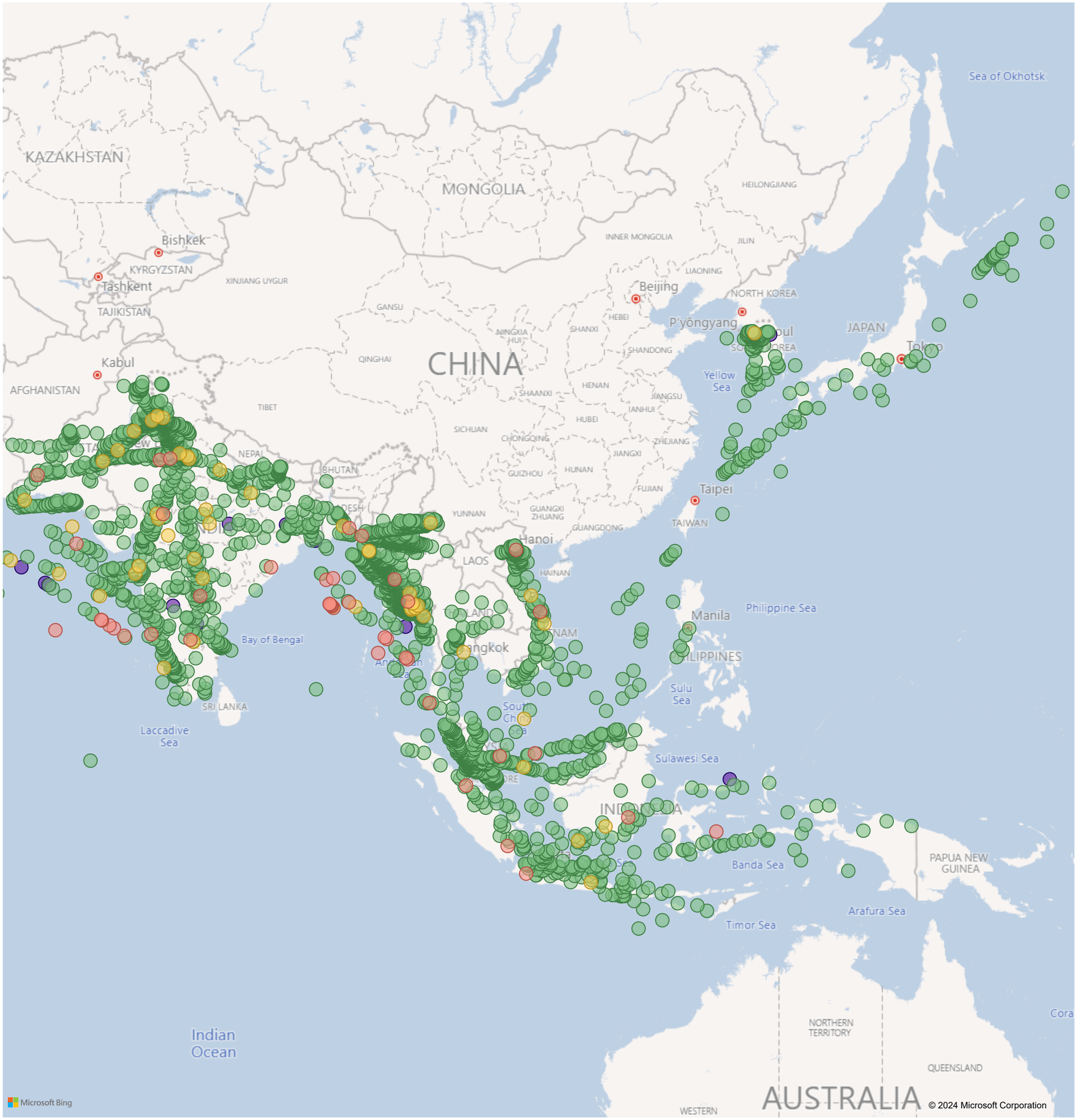


Focus on ASPAC FIRs - Map View

Region:
ASPAC

Period:
2021 Aug - 2023 Dec

Position of GPS Signal Loss Occurrences in TOP 20 FIR per Event Duration



Event Duration

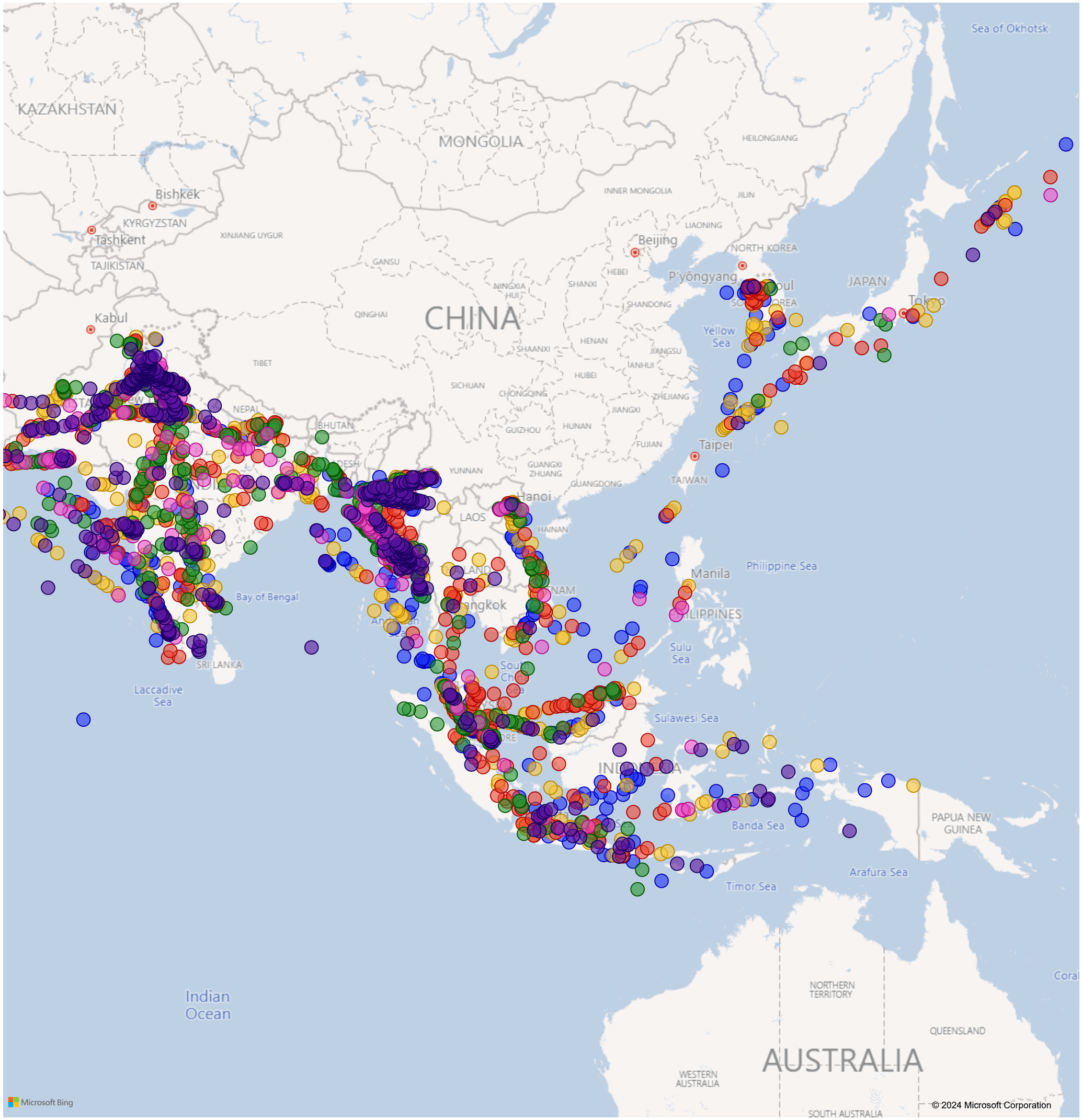
- +120 minutes
- <30 minutes
- 30 to 60 minutes
- 60 to 120 minutes

Focus on ASPAC FIRs - Map View

Region:
ASPAC

Period:
2021 Aug - 2023 Dec

Position of GPS Signal Loss Occurrences in TOP 20 FIR per UTC time buckets



UTC Time Buckets

- T1 0000-0400UTC
- T2 0040-0800UTC
- T3 0080-1200UTC
- T4 0012-1600UTC
- T5 0016-2000UTC
- T6 0020-0000UTC

Focus on ASPAC FIRs - Map View

Region:
ASPAC

Period:
2021 Aug - 2023 Dec

Position of GPS Signal Loss Occurrences in TOP 20 FIR per Event year