ADS-B MESSAGES AS A SOURCE OF OPERATIONAL DATA IN AVIATION

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Abstract

Automatic dependent surveillance has been becoming one of the technologies for aircraft surveillance. ADS-B messages which are broadcast from the aircraft to the ground contain many valuable information about the state and position of the aircraft. This paper presents more options for airline and airport operators how to utilize the information derived from the ADS-B messages. Particularly it deals with unstabilized approach detection, evaluation of the navigation integrity and arrivals and departures recording.

Keywords

ADS-B message, unstabilized approach, navigation integrity category, arrivals and departures recording

1. Introduction

The utilization of ADS-B messages as a source of surveillance data is just a tip of an iceberg of all possible options what to use them for. Receiving of ADS-B messages can be beneficial not only for the air traffic services but also for both airline and airport operators. This study shows the utilization of ADS-B messages for detection of unstabilized approaches, for evalutaion of the navigation integrity and for getting records of arrivals to and departures from a given airport. The aim of the study is to show examples of operational data that can be derived the ADS-B messages.

2. Unstabilized Approach Detection

There are over 100 000 landings at airports all over the world every day. (IATA, 2017) Although flight safety has been kept on a high level; the critical phases of flight which are in this case approach and landing are still risk. During a stabilized approach, aircraft is flying in the right configuration, it is flying at required velocity, engines are producing the required power and the aircraft is established on the right vertical and lateral path. Having one of these conditions breached means the approach is not stabilized and the risk of incident or accident during landing grows. In case an approach is not stabilized, a missed approach procedure shall be conducted.

Flying a stabilized approach at 1000 ft above the aerodrome level makes the flight crew able to pay a full attention to the instruments, to keep the situational awareness and to keep the mental capacity for situations in which any extraordinary or unexpected actions are required during this critical phase of flight.

According to (IATA, 2017), an unstabilized approach was a contributing factor in 16 % of aircraft accidents that happened during approach or landing between 2012 and 2016.

The approach is not stabilized when one of the defining parameters is excessed as shown in Table 1.

Table 1: Excessive flight parameter deviation criteria. Source: (Airbus, 2006).

Parameter	Not stabilized approach criteria
Airspeed	Lower than V_{APP} – 5 kt or greater than V_{APP} + 10 kt
Vertical Speed	Greater than –1000ft/min
Pitch Attitude	Pitch limits are given in airline Standard Operating Procedures
Bank Angle	Greater than 7 degrees
LOC deviation	¼ dot
Glide Slope deviaton	1 dot

Aviation authorities or airline flight safety departments may be interested in having the opportunity to detect the unstabilized approaches on their own based on the ADS-B data received. An algorithm to detect the unstabilized approaches has been introduced during this study.

To be able to compare all flights it is necessary to find comparable parameters which are the same for all flights. The only clear and comparable parameter is the vertical velocity which should not be greater than 1000 ft/min while descending. Other parameters are dependent on the aircraft size or on the airline procedures which may differ.

The detection was done using ADS-B data received on 31st May 2018 between 2140 UTC and 2200 UTC. The data used were obtained by ADS-B receivers owned by the Faculty of Transportation Sciences of the Czech Technical University in Prague. One aircraft was detected as it was performing an unstabilized approach when its vertical velocity was still greater than 1000 ft/min (orange arrows in Fig. 1) below 1000 ft (blue arrow in Fig. 1) above the airport. The aircraft can be identified with ICAO address 49D14C (A319).

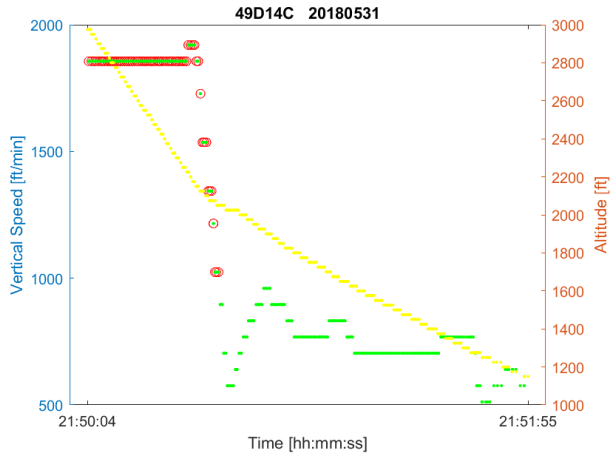

Figure 1: Vertical speed (in green, red circle marks exceeding values) and altitude (in yellow) of the aircraft with ICAO address 49D14C. Source: Authors.

3. Evaluation of the Navigation Integrity

Integrity is an important attribute of every system. It is the system´s ability to identify incorrect input information which may cause an erroneous behavior of the system. Regarding the position information derived from the ADS-B messages, the navigation integrity category (NIC) shall be known. There are 12 navigation integrity categories (Table 2) for which a Radius of Containment RC is defined.

Table 2: Navigation Integrity Categories and Radius of Containment. Source: (RTCA).

	Radius of Containment R_C
NIC0	R_C unknown
NIC1	R_C < 20 NM (31,04 km)
NIC2	R_C < 8 NM (14,816 km)
NIC3	R_C < 4 NM (7,408 km)
NIC4	R_C < 2 NM (3,704 km)
NIC5	R_C < 1 NM (1852 m)
NIC6	R_C < 0,6 NM (1111,2 m)
	R_C < 0,5 NM (926 m)
NIC7	R_C < 0,2 NM (370,4 m)
NIC8	R_C < 0,1NM (185,2 m)
NIC9	R_C < 75 m
NIC10	R_C < 25 m
NIC11	R_C < 7,5 m

Radius of containment defines a circle out of which the actual position of the aircraft can be found with a probability given by the Source Integrity Level (SIL) value. SIL is a constant value given for each aircraft based on offline analysis of its avionics and the value can also be derived from the ADS-B messages. (ICAO,2011)

This part of the study provides a statistic based on ADS-B data showing the percentage ratio of the navigation integrity categories within a given sample of data. Moreover, the airborne situation is displayed in a map of the Czech Republic. Comparing more airborne situations it can be decided whether there is an area in which aircraft´s position data integrity is degraded as a result of some external factor (eg. GNSS jamming).

An analysis of data from 17th March 2019 was performed. Table 3 shows the percentage of the navigation integrity categories in a period of three minutes after every second UTC hour.

Table 3: Percentage ratio of the navigation integrity categories from 17th March 2019. Source: Authors.

UTC	*00 00*	*02 00*	*04 00*	*06 00*	*08 00*	*10 00*	*12 00*	*14 00*	*16 00*	*18 00*	*20 00*	*22 00*
NIC 0				6	2	5	2	1,3	4	5	7	
NIC 1												
NIC 2												
NIC 3												
NIC 4												
NIC 5				0,1								1
NIC 6				3	2	0,01	0,9	2,9		4	1	
NIC 7	28		0,9	50,9	27	11,7	28	24,7	0,01	28	20	1
NIC 8	72	100	99,1	34	63	79	64	67,9	91	59	68	93
NIC 9					5	4	5	3,1	5	1		5
NIC 10				6	1	0,29	0,1	0,1	0,39	3	4	
NIC 11												

Most of the position data received from aircraft belong to navigation integrity category 8. Only after 0600 UTC most of the data belong to category 7.

Data that belong to categories 0-6 shall not be used for establishing of separation between aircraft. Only few percent of data belong to these categories.

Figure 2 shows an example of the data from 17th March 2019 between 0600 UTC and 0603 UTC displayed in the map of the Czech Republic.

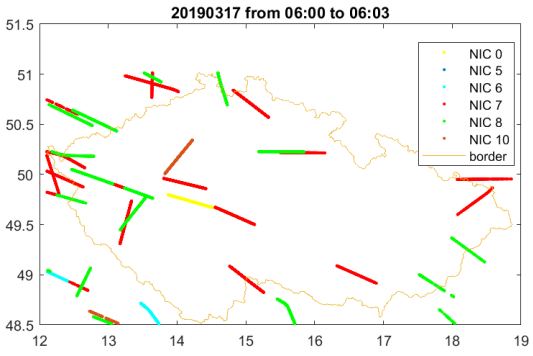

Figure 2: A map of the Czech Republic showing flight trajectories that are coloured according to the navigation integrity category. Source: Authors.

An area in which aircraft would provide position data with degraded integrity as a result of an external factor was not identified during this study.

4. Arrivals and Departures Recording

This part of the study shows that ADS-B data can also be used to make records of aircraft that landed at a given airport or took off. The record contains:

- ICAO address to identify the aircraft;
- Aircraft category;

- Aircraft registration or flight callsign;
- Information whether it is arrival or departure;
- Date and time of the event.

An example record (Figure 3) is introduced based on the data from 17th March 2019 between 1600 UTC and 1620 UTC and it shows arrivals and departures to and from the Prague Václav Havel airport.

	1	2	3	4	5
1	424377	Large	AFL2015_	Departure	20190317_16:03
2	3C6DCB	No Category Info	EWG9TU__	Arrival	20190317_16:05
3	44CDC2	No Category Info	BEL3PR__	Arrival	20190317_16:08
4	4CA2D4	Large	RYR62EV_	Arrival	20190317_16:11
5	49D056	No Category Info	CSA481__	Arrival	20190317_16:16
6	471E16	No Category Info	CSA726__	Departure	20190317_16:18
7	4CA806	No Category Info	RYR58K__	Arrival	20190317_16:19

Figure 3: Final record [1]. Source: Authors.

5. Discussions

Unstabilized approaches may result in aircraft incident or accident during landing. Therefore, it is key to detect them and to identify the reasons why they happen. To help aviation authorities or airline flight safety departments to detect this kind of approaches, an ADS-B derived data detection has been introduced.

Knowing the integrity of the position data that are broadcast via ADS-B is key to determine whether the position data is suitable to be used for establishing separation between aircraft. The navigation integrity category is being broadcast within the ADS-B messages and can be obtained by decoding them.

Finally, airport operators may benefit from having own ADS-B receiver as it has come out that it is possible to make records about the aircraft movements at the airport.

6. Conclusion

Receiving of the ADS-B data can be beneficial for operators of airlines or airports. They can use the ADS-B derived information to evaluate operational situations. Three different operational areas have been introduced in this paper showing that the utilization of the ADS-B data is much wider than only for air traffic services and surveillance purposes.

First, ADS-B data analysis have been done to evaluate approaches and to identify approaches that are not stabilized. During the observed period one aircraft was found flying an approach which was not stabilized.

Second, navigation integrity has been evaluated on the basis of the information provided within ADS-B messages. A statistic showing percentage ratio of the navigation integrity categories has been obtained based on the data analysis.

Furthermore, it was shown that ADS-B messages can be used to create records of departures and arrivals at a given airport.

The results show that it is possible to use ADS-B messages to obtain operational data and to evaluate different operational situations.

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[1] First column contains the a/c ICAO address, the second column contains the a/c category, the third column shows the callsign, the fourth column states whether it is arrival or departure and the fifth column contains the date and time.