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TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) – SELECTED STATISTICAL AND PERFORMANCE DATA IN CORE EUROPEAN AIRSPACE

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Abstract

The main purpose of this document is to present a selection of statistical and performance data of Traffic Alert and Collision Avoidance System (TCAS) obtained through radar recordings in core European airspace. The data is intended to support safety and performance studies, as well as R&D activities. Some data has been obtain directly from aircraft operators. No conclusions are drawn on the data presented in this document.

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DOCUMENT APPROVAL

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Executive Summary

TCAS RA not followed is one of the Top 5 ATM operational risk priorities. To supplement the previously conducted studies, including the study of pilot compliance with TCAS (Traffic Alert and Collision Avoidance System) Resolution Advisories (RA), this document provides detailed statistical data on TCAS RAs. The data was collected in core European airspace over 365 consecutive days (in pre-COVID traffic volumes).

The main purpose of this document is to present a selection of statistical and TCAS performance data. The data is intended to support safety and performance studies, as well as R&D activities. Some data has been obtain directly from aircraft operators to provide additional performance data.

No conclusions are drawn on the data presented in this document.

1 Objective

The purpose of this document is to present statistical data and performance data of TCAS in core European airspace. The data has been obtain through radar recording and, in some cases, directly from aircraft operators. No conclusions are drawn on the data presented in this document.

As specified in EU Regulation 2019/123, Network Manager is tasked with identifying operational safety hazards at European ATM network level and assess the associated network safety risk. To fulfil this obligation, the Network Manager implemented a dedicated risk identification and monitoring process.

The current ATM Top 5 operational risk priorities are:

- Blind spot (conflict between aircraft in close proximity not detected by air traffic controller);
- TCAS RA not followed;
- Flight without a transponder or with a dysfunctional one;
- Detection of potential runway conflict by air traffic controllers;
- Sudden, high energy runway conflict.

This study has been carried out to support the "TCAS RA not followed"[1] operational risk in order to provide operational data assessing pilot responses to TCAS RAs, as well as TCAS operational mode and serviceability. This study supplements the survey conducted in 2017[2] in which a significant number of pilots admitted that RAs are often not followed. Also, previous monitoring activities established that pilots often do not follow RAs correctly[3].

In the autumn of 2020, EUROCONTROL released the result of the "*assessment of pilot compliance with TCAS RAs, TCAS mode selection and serviceability using ATC radar data*" study. This study triggered discussions amongst Stakeholders and it became evident that in order to support an informed discussion and any follow up action, a comprehensive view on TCAS performance and statistical data is needed. The current study is using the same data set as the above-mentioned pilot compliance study.

[1] See SKYbrary article.

[2] Available on SKYbrary.

[3] EVAIR Safety Bulletin no 14 (2010-2014).

2 Introduction

2.1 Data set

EUROCONTROL used radar data, which was gathered recently in core European airspace[4] over a period of 12 months, to extract comprehensive TCAS statistics and performance data.

When a Resolution Advisory (RA) is generated the aircraft's transponder can downlink a message providing details of RAs and RA termination to a Mode S ground station on each radar interrogation. Each downlinked RA message also contains details concerning the threat aircraft. These RA downlink messages together with the ATC track data were used obtain the statistical data and performance data presented in this document. The data is limited only to the events in which at least one aircraft involved received an RA.

The recording sets were obtained from three different sources, each set covering 365 consecutive days. The recordings overlapped for a period of 9 months (see Figure 2-1).

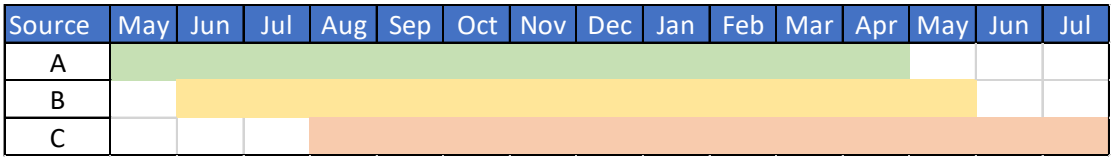

Figure 2-1: Recording periods

The data is presented in tables and, where appropriate, illustrated by graphs.

2.2 Data limitations and accuracy

The Reader is advised to note the following regarding the limitations and accuracy of the data:

- Statistical data presented in this document has been obtained through ATC radar recordings. Radar data is in turn processed by ATC trackers every 4 seconds. Additionally, some latency may also be caused by rotation of a radar antenna. Therefore, events such as RAs or RA termination occur in the preceding 4-second period but the timing cannot be precisely determined (RA messages are downlinked without a timestamp).
- Altitudes and vertical rates may be inaccurately determined by the ATC system tracker. In order to deliver optimal display performance of radar data to air traffic controllers, the ATC system tracker software makes assumptions regarding the estimated position of tracks and approximates the data accordingly. The "tracker effect" has been significantly reduced by applying additional filtration.
- All aircraft were assumed to be equipped with TCAS II version 7.1.

[4] Airspace in western and central part of Europe where traffic density is high.

- Some data and results have been obtained from the radar recordings (e.g. RA types from RA downlink messages), while some are the results of calculations obtained from recorded trajectories (e.g. calculation of the Closet Point of Approach – CPA). The recorded trajectories are subject to the limitation outlined above and any calculations based on them carry some degree of uncertainty.

2.3 General monitoring results

The monitoring period covered 9.02 million flight hours, of pre-Covid European traffic. That represents approximately 55% of all flight hours in EUROCONTROL Area (ESRA08) in the corresponding period. There were 1256 first RAs[5] recorded in 1084 encounters[6]. Out of 1256 first recorded RAs 14 were deemed to be anomalous (non-nominal) – see section 2.5 for more details.

2.4 RA types

In order to provide the Reader with a higher level of detail regarding the recorded RAs, the RA names not providing their vertical sense have been amended to indicate the sense, e.g. for a Level Off RA while climbing a “LO (DN)” abbreviation is used rather than usual “LO” or MVS (LCL) instead of MVS.

Level Off RAs (LO) always require a reduction of the vertical speed to 0 ft/min., i.e. a level off. A Level Off RA can be issued in Upward Sense[7] or Downward Sense[8].

For initial RAs or some subsequent RAs (strengthening RAs):

- a LO (UP) (Level Off Upward Sense RA) is typically issued while the aircraft is descending and will prohibit any further descent by displaying the red arc (zone) below zero on the cockpit instruments;
- a LO (DN) (Level Off Downward Sense RA) RA is typically issued while the aircraft is climbing and will prohibit any further climb by displaying the red arc (zone) above zero on the cockpit instruments.

For **weakening RAs** (issued to limit a deviation from the cleared level when the previously issued RA has already provided sufficient separation):

- a LO (UP) (Level Off Upward Sense RA) is issued when a climb (required by the previous RA) is no longer needed and will prohibit any further climb by displaying the red arc (zone) above zero on the cockpit instruments;

[5] First RA refers to the initial RA issued to an aircraft during an encounter. The first RA may or may not be the only RA in this encounter.

[6] Cases when two aircraft are in proximity and one or both of them receive an RA.

[7] RA downlink bit 43 = 0

[8] RA downlink bit 43 = 1

- a LO (DN) (Level Off Downward Sense RA) is issued when a descent (required by the previous RA) is no longer needed and will prohibit any further descent by displaying the red arc (zone) below zero on the cockpit instruments.

Monitor Vertical Speed RAs (MVS) are preventive RAs[9] that prohibit certain vertical rates (0, 500, 1000, 2000 ft/min.) either for climb or descent (the value of the prohibited vertical speeds is not available in the RA downlink messages). Here, these RAs are referred to as MVS (LCL) (Limit Climb)[10] for RAs prohibiting any climb rates or MVS (LDE) (Limit Descent)[11] for RAs prohibiting any descent rates.

Maintain Vertical Speed RAs that require the aircraft to continue the current climb are referred to as MaVS (CL)[12] while the RAs that require the aircraft to continue the current descent are referred to as MaVS (DE)[13].

The list all RA abbreviations is shown in Table 2-1. RAs in grey-shaded rows were not recorded during this monitoring activity and they are listed here only for completeness. RAs marked with an asterisk (*) are only possible as a subsequent RA, not as the first RA in the encounter.

Table 2-1: Abbreviations of RA types

Abbreviation	RA
CL	Climb
DE	Descend
XCL	Crossing Climb
XDE	Crossing Descend
ICL *	Increase Climb *
IDE *	Increase Decent *
RCL *	Reversal Climb *
RDE *	Reversal Decent *
LO (UP)	Level Off (upward sense)
LO (DN)	Level Off (downward sense)
MaVS (CL)	Maintain Vertical Speed (while climbing)
XMaVS (CL)	Crossing Maintain Vertical Speed (while climbing)
MaVS (DE)	Maintain Vertical Speed (while descending)
XMaVS (DE)	Crossing Maintain Vertical Speed (while descending)
MVS (LCL)	Monitor Vertical Speed (limit climb)
MVS (LDE)	Monitor Vertical Speed (limit descent)
COC	Clear of Conflict (RA termination)

[9] An RA that instructs the pilot to avoid certain deviations from current vertical rate,

[10] RA downlink bit 43 = 1

[11] RA downlink bit 43 = 0

[12] RA downlink bit 43 = 0

[13] RA downlink bit 43 = 1

Other abbreviations used in this document can be found in Table 6-1 on page 50. A Glossary of Terms is provided in section 6.2 on page 50.

2.5 Non-nominal RA sequences

During the course of an encounter, the RA strength is evaluated every second and it will be strengthened, reversed or weakened, as needed. While some RAs will change in the course of the encounter, some will be retained until the RA is terminated. In the vast majority of the cases, the recorded RAs in each sequence went through an expected sequence of single, weakening, strengthening or reversal RAs.

However, occasionally an RA sequence was observed which was deemed non-nominal (anomalous). Those were:

A. The first recorded was an RA which is possible only as a subsequent RA (RCL, RDE, ICL, IDE).

B. Second, third, or forth RA in sequence was recorded with the termination bit set (RAT=1).

C. The RA was split. That could have occurred due to a loss surveillance or the geometry of encounter (e.g. the aircraft first manoeuvres in such way that the RA termination is justified only to manoeuvre later towards the threat aircraft), the RA terminated (with or without a Clear of Conflict annunciation) only to be started again against the same intruder (instantaneously or after several seconds).

D. The recorded RA sequence was illegal (not allowed) by the TCAS logic, e.g. an RA sense changed with a reversal (from Climb RA to Descend RA or other way around). In reality, the sequence was most likely legal but not all RAs in the sequence were recorded, rendering the sequence illegal.

In the examined data set of 1256, there were 14 (1.1%) RA sequences deemed non-nominal (see Table 2-2). The abbreviation used for RA types are explained at the back of the document.

Non-nominal RA sequences have been excluded from further calculations and statistics.

Table 2-2: Non-nominal RA sequences encounters

RA sequence	Number	Anomaly type
RDE – LO (DN)	1	A
RCL – LO (UP)	1	A
RCL	1	A
ICL – RDE	1	A & B
DE – LO (DN)	2	B
LO (DN) – XDE – DE	1	B
LO (UP) – DE – LO (DN)	1	B
LO (UP) – MVS (LDE) – CL	1	C
DE – LO (DN)	1	C
CL – LO (UP)	1	C

CL – LO (UP) – MVS (LDE)	1	C
DE – CL – RDE	1	D
LO (UP) – ICL – MaVS (DE)	1	D
Total:	**14**	

3 Results

3.1 RA and encounter frequency

The frequency of RAs and encounters are presented in Table 3-1 below. Additional information concerning RA and TA frequencies is available in Section 4 on page 48.

Table 3-1: RA and encounter frequency

Event	Number
1st RAs	1242
Frequency (flight hours/RA)	7259
Frequency (RAs/day)	3.4
Encounters	1072
Frequency (flight hours/encounter)	8410
Frequency (encounter/day)	2.9

3.2 RA sequences statistics

During an encounter, an aircraft may receive one or more RAs. All the RAs received in one encounter are referred to as an *RA sequence*.

There were 32 types of non-anomalous RA sequence recorded. The number of RAs each of the sequence types is shown in (see Table 3-2). Table 3-3 shows the number of each unique sequence type and the overall total of RAs.

Table 3-2: RA sequence types

	1st RA	2nd RA	3rd RA	4th RA	Number	Percentage
1	LO (DN)				413	33.3%
2	LO (UP)				361	29.1%
3	MVS (LDE)				116	9.3%
4	CL	LO (UP)			91	7.3%
5	DE	LO (DN)			66	5.3%
6	CL				59	4.8%
7	DE				52	4.2%
8	MVS (LCL)				30	2.4%
9	LO (UP)	CL			10	0.8%
10	MVS (LDE)	LO (UP)			6	0.5%
11	LO (DN)	DE	LO (DN)		6	0.5%
12	MVS (LCL)	LO (DN)			4	0.3%
13	DE	MaVS (CL)			3	0.2%
14	LO (UP)	CL	LO (UP)		3	0.2%
15	CL	RDE			2	0.2%
16	XDE	LO (DN)			2	0.2%
17	MVS (LCL)	DE			2	0.2%
18	LO (DN)	DE			2	0.2%

	1st RA	2nd RA	3rd RA	4th RA	Number	Percentage
19	DE	XCL	LO (UP)		1	0.1%
20	CL	ICL			1	0.1%
21	CL	LO (UP)	CL		1	0.1%
22	CL	RDE	LO (DN)		1	0.1%
23	XDE				1	0.1%
24	DE	IDE	RCL	LO (UP)	1	0.1%
25	DE	RCL			1	0.1%
26	DE	RCL	LO (UP)		1	0.1%
27	MVS (LDE)	CL			1	0.1%
28	MVS (LDE)	CL	LO (UP)		1	0.1%
29	LO (UP)	CL	MaVS (DE)		1	0.1%
30	MaVS (CL)	LO (UP)			1	0.1%
31	MaVS (DE)				1	0.1%
32	MaVS (DE)	LO (DN)			1	0.1%
				Total:	**1242**	**100.0%**

Table 3-3: Number of RAs in each sequence

Number of RAs in a sequence	Number of unique sequences	Number of recorded sequences	Percentage
1	8	1033	83.2%
2	15	193	15.5%
3	8	15	1.2%
4	1	1	0.1%

3.3 Duration of RA sequences

Table 3-4 below shows the maximum, average and median duration (in seconds) for each non-anomalous RA sequence.

Table 3-4: Duration of RA sequences

1st RA	2nd RA	3rd RA	4th RA	Number	Sequence Duration Max [s]	Sequence Duration Average [s]	Sequence Duration Median [s]
LO (DN)				413	316	27	28
LO (UP)				361	204	28	28
MVS (LDE)				116	40	19	20
CL	LO (UP)			91	44	29	28
DE	LO (DN)			66	88	31	32
CL				59	84	15	12
DE				52	68	14	12
MVS (LCL)				30	40	19	20
LO (UP)	CL			10	24	16	16
MVS (LDE)	LO (UP)			6	36	33	34

1st RA	2nd RA	3rd RA	4th RA	Number	Sequence Duration Max [s]	Sequence Duration Average [s]	Sequence Duration Median [s]
LO (DN)	DE	LO (DN)		6	28	21	22
MVS (LCL)	LO (DN)			4	20	18	18
DE	MaVS (CL)			3	32	29	32
LO (UP)	CL	LO (UP)		3	24	15	12
CL	RDE			2	36	30	30
XDE	LO (DN)			2	24	22	22
MVS (LCL)	DE			2	20	20	20
LO (DN)	DE			2	28	22	22
DE	MaVS (CL)	LO (UP)		1	24	24	24
CL	ICL			1	32	32	32
CL	LO (UP)	CL		1	24	24	24
CL	RDE	LO (DN)		1	28	28	28
XCL				1	20	20	20
DE	IDE	RCL	LO (UP)	1	28	28	28
DE	RCL			1	16	16	16
DE	RCL	LO (UP)		1	32	32	32
MVS (LDE)	CL			1	20	20	20
MVS (LDE)	CL	LO (UP)		1	20	20	20
LO (UP)	CL	MaVS (DE)		1	12	12	12
MaVS (CL)	LO (UP)			1	68	68	68
MaVS (DE)				1	4	4	4
MaVS (DE)	LO (DN)			1	32	32	32

3.4 Duration of each RA in a sequence

Table 3-5 below shows how many RA sequences were observed for each duration interval. Underneath, Table 3-6 lists overall Maximum, Average and Median duration values for all RA sequences. The distribution of total RA sequence duration is illustrated in Figure 3-1.

Table 3-7 on page 22 shows the maximum, average and median durations (in seconds) for each RA in a sequence.

Table 3-5: Total duration of RA sequences

Total duration [s]	Number	Percentage
4	60	4.8%
8	100	8.1%
12	121	9.7%
16	121	9.7%
20	132	10.6%
24	150	12.1%
28	118	9.5%
32	132	10.6%
36	135	10.9%

Total duration [s]	Number	Percentage
40	129	10.4%
>41	44	3.5%

Table 3-6: Maximum, Average and Median values for total RA sequence duration

Value	Seconds
Max	316
Average	25
Median	24

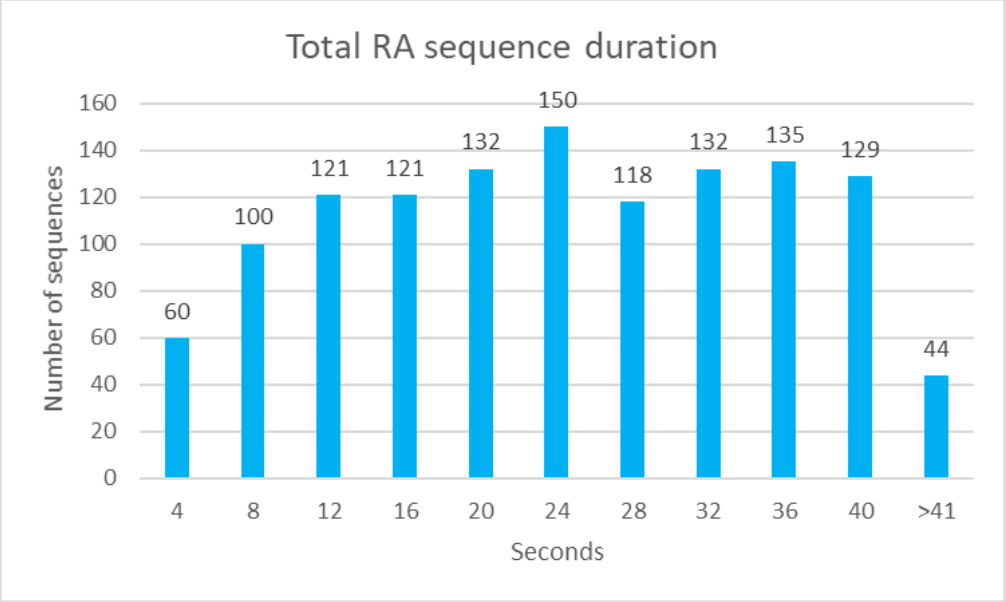

Figure 3-1: Total RA duration distribution

The figures below (Figure 3-2 through Figure 3-9) illustrate the distributions of duration of the whole RA sequence (for sequences that were recorded at least 30 times).

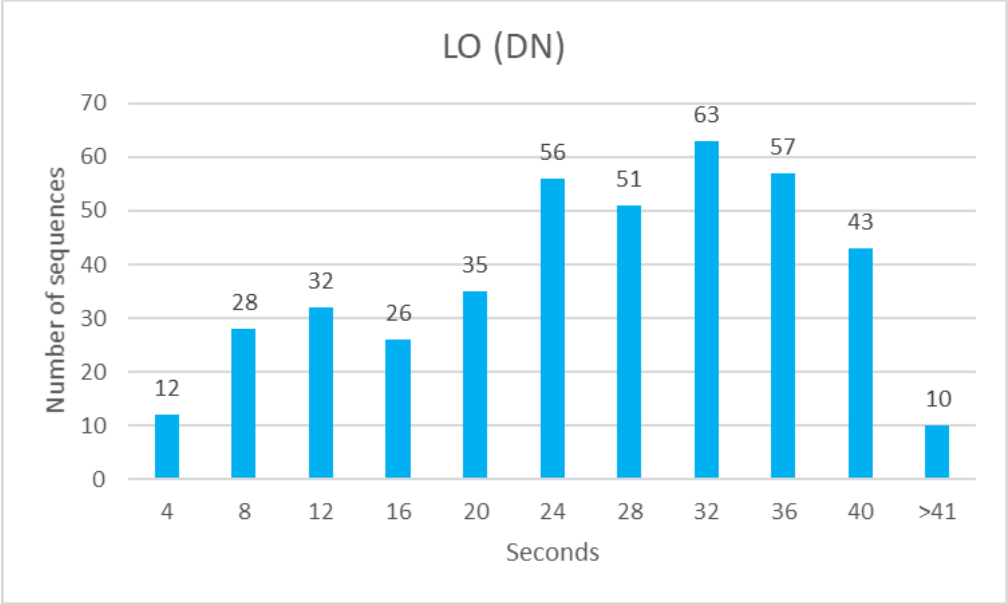

Figure 3-2: LO (DN) sequence duration distribution

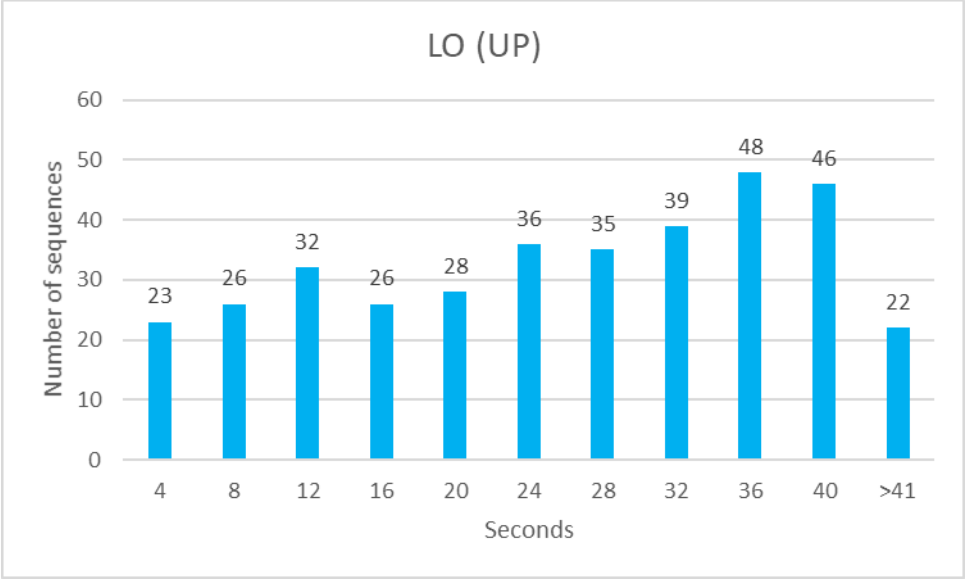

Figure 3-3: LO (UP) sequence duration distribution

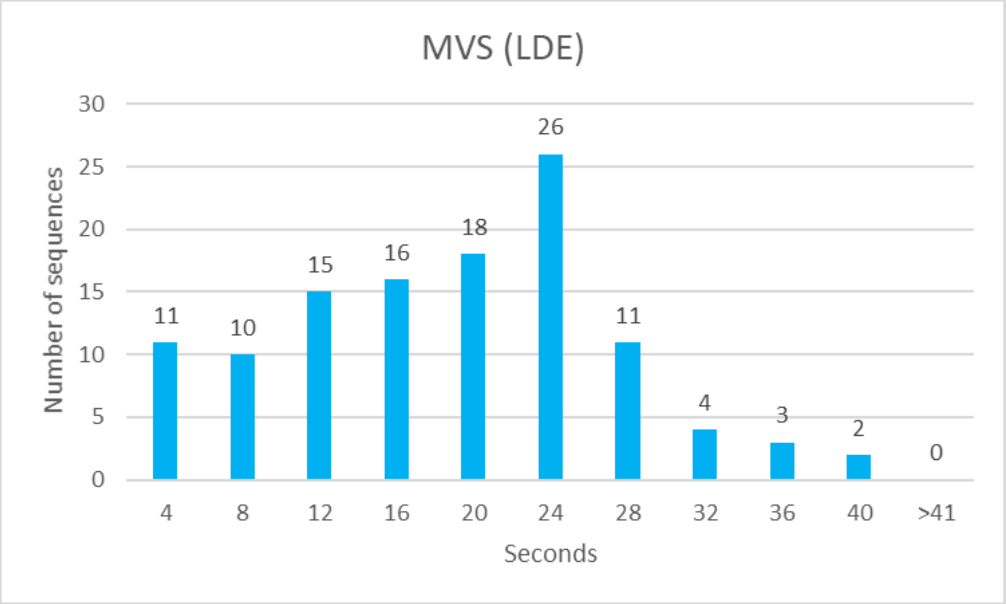

Figure 3-4: MVS (LDE) sequence duration distribution

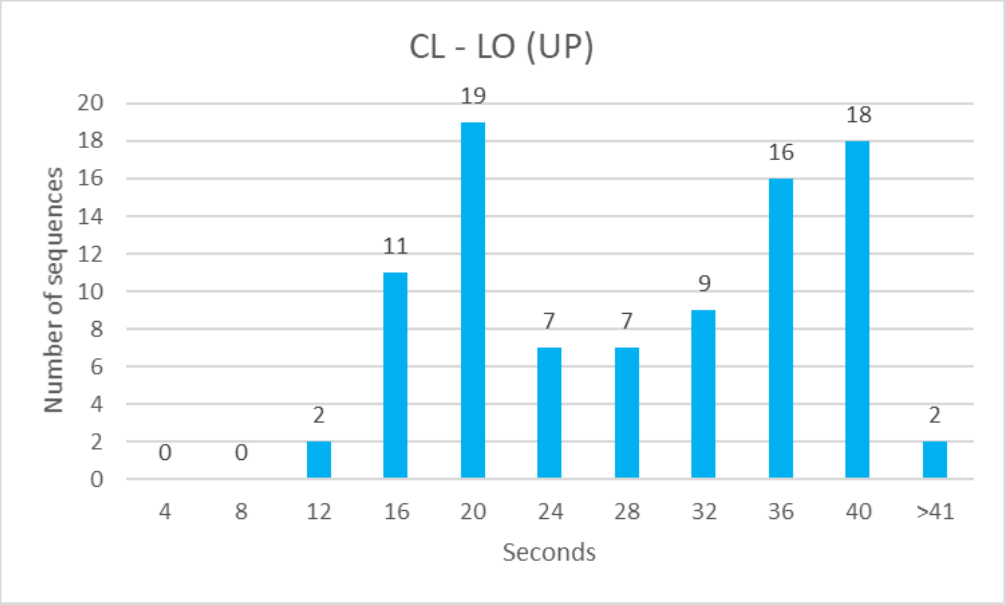

Figure 3-5: CL – LO (UP) sequence duration distribution

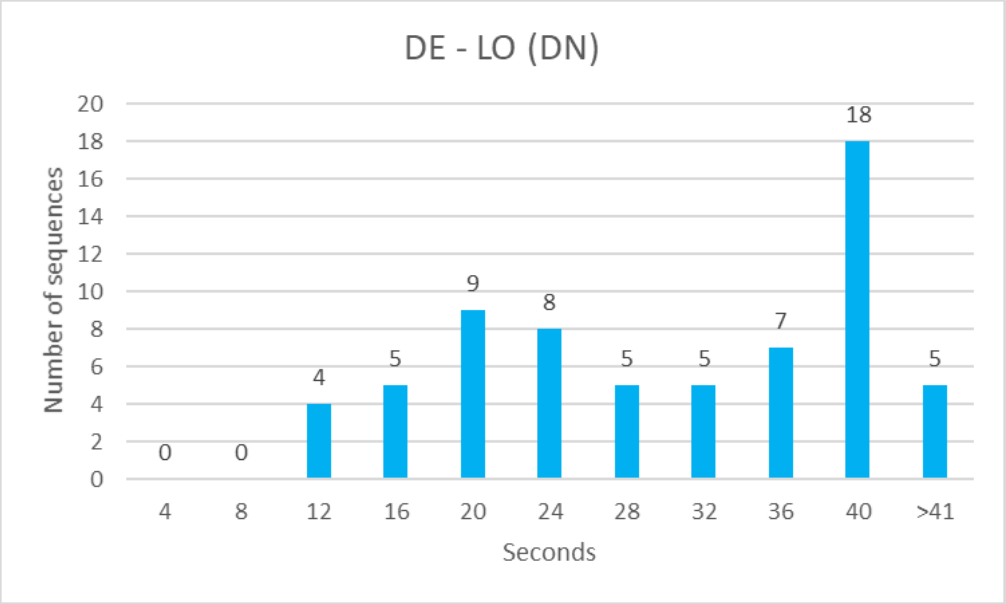

Figure 3-6: DE – LO (DN) sequence duration distribution

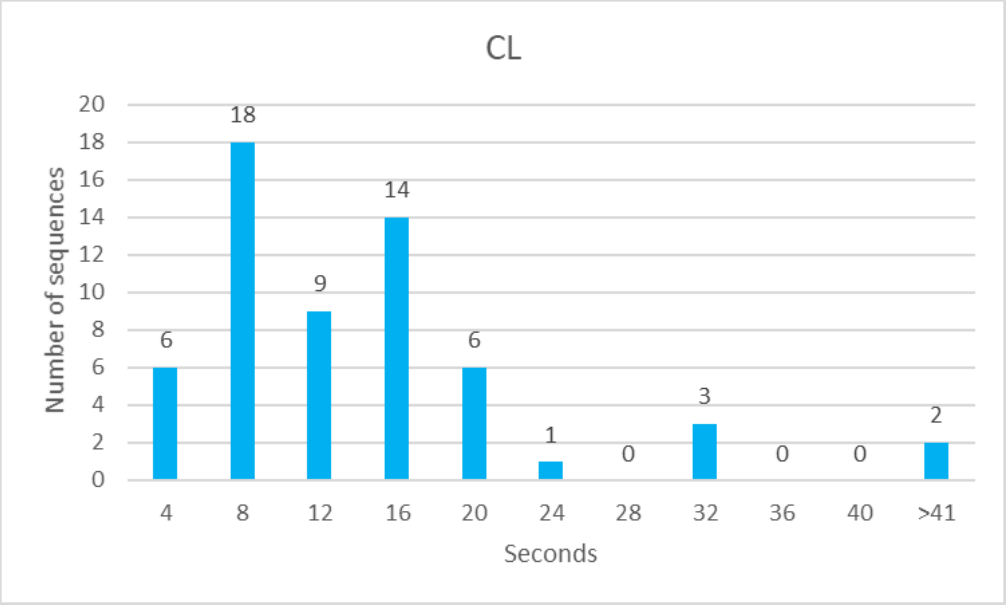

Figure 3-7: CL sequence duration distribution

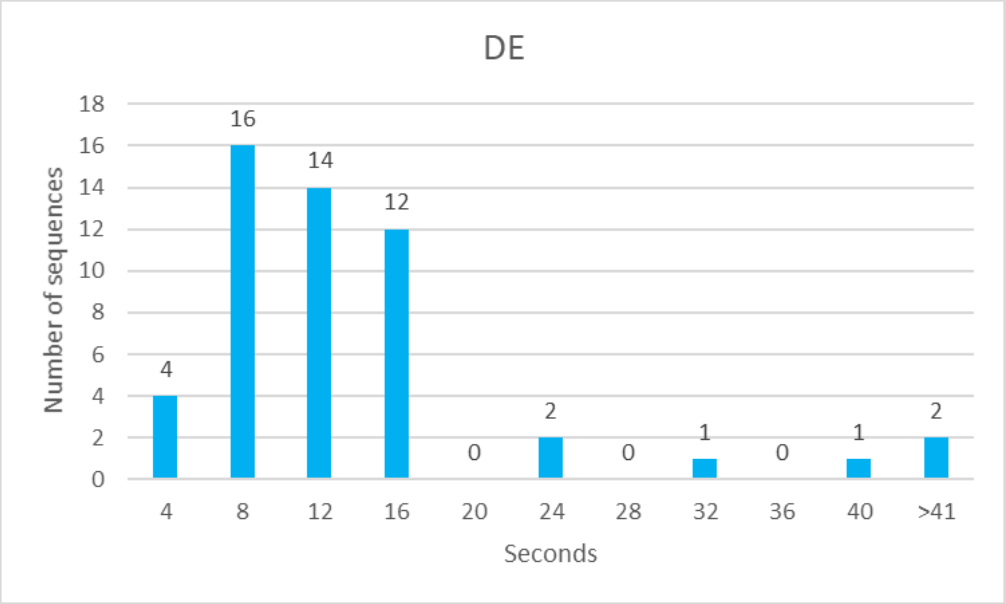

Figure 3-8: DE sequence duration distribution

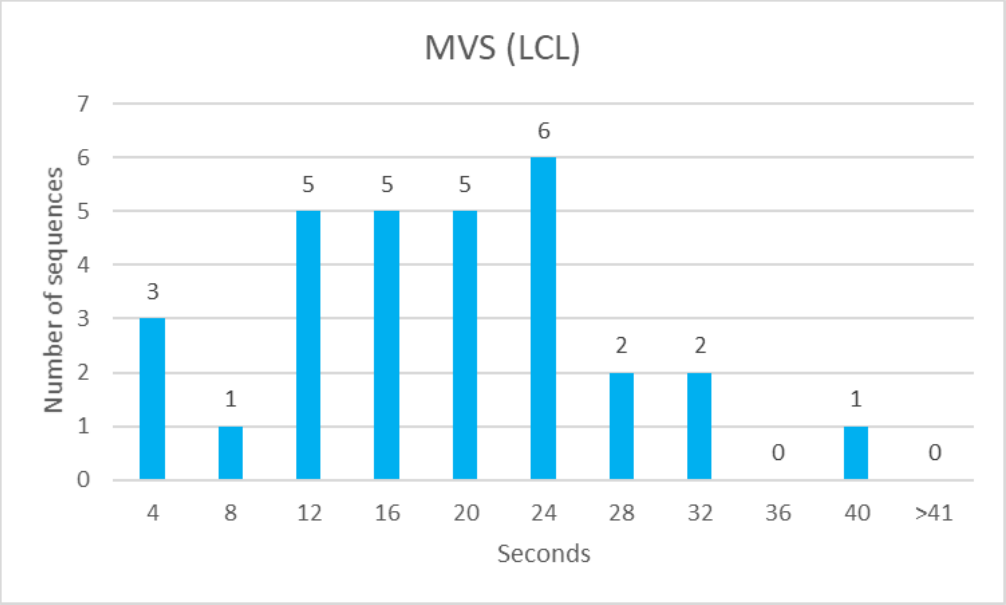

Figure 3-9: MVS (LCL) sequence duration distribution

Table 3-7: Duration of each RA in a sequence

1st RA	2nd RA	3rd RA	4th RA	Number	1st RA Duration Max [s]	1st RA Duration Average [s]	1st RA Duration Median [s]	2nd RA Duration Max [s]	2nd RA Duration Average [s]	2nd RA Duration Median [s]	3rd RA Duration Max [s]	3rd RA Duration Average [s]	3rd RA Duration Median [s]
LO (DN)				413	316	27	28						
LO (UP)				361	204	28	28						
MVS (LDE)				116	40	19	20						
CL	LO (UP)			91	20	11	12	36	18	20			
DE	LO (DN)			66	36	12	12	60	19	16			
CL				59	84	15	12						
DE				52	68	14	12						
MVS (LCL)				30	40	19	20						
LO (UP)	CL			10	12	9	10	16	7	6			
MVS (LDE)	LO (UP)			6	24	14	10	16	7	4			
LO (DN)	DE	LO (DN)		6	12	6	4	12	11	12	20	16	16
MVS (LCL)	LO (DN)			4	16	9	8	16	9	8			
DE	MaVS (CL)			3	20	9	4	8	5	4			
LO (UP)	CL	LO (UP)		3	8	8	8	12	9	8	16	12	12
CL	RDE			2	20	14	14	8	8	8			
XDE	LO (DN)			2	16	14	14	8	6	6			
MVS (LCL)	DE			2	20	18	18	20	12	12			
LO (DN)	DE			2	16	12	12	12	10	10			
DE	MaVS (CL)	LO (UP)		1	8	8	8	12	12	12	4	4	4
CL	ICL			1	8	8	8	12	12	12			
CL	LO (UP)	CL		1	8	8	8	4	4	4	12	12	12

1st RA	2nd RA	3rd RA	4th RA	Number	1st RA Duration Max [s]	1st RA Duration Average [s]	1st RA Duration Median [s]	2nd RA Duration Max [s]	2nd RA Duration Average [s]	2nd RA Duration Median [s]	3rd RA Duration Max [s]	3rd RA Duration Average [s]	3rd RA Duration Median [s]
CL	RDE	LO (DN)		1	4	4	4	12	12	12	4	4	4
XCL				1	4	4	4						
DE	IDE	RCL	LO (UP)	1	4	4	4	4	4	4	4	4	4*)
DE	RCL			1	56	56	56	12	12	12			
DE	RCL	LO (UP)		1	16	16	16	8	8	8	4	4	4
MVS (LDE)	CL			1	28	28	28	4	4	4			
MVS (LDE)	CL	LO (UP)		1	8	8	8	8	8	8	16	16	16
LO (UP)	CL	MaVS (DE)		1	12	12	12	12	12	12	4	4	4
MaVS (CL)	LO (UP)			1	8	8	8	12	12	12			
MaVS (DE)				1	32	32	32						
MaVS (DE)	LO (DN)			1	8	8	8	4	4	4			

*) For 4th RA in the DE – IDE– RCL – LO (UP) sequence, the values were 4 seconds for Maximum Duration, Average and Median.

3.5 Distribution of altitudes of first RAs in each sequence

The figures below (Figure 3-10 through Figure 3-18) illustrate the distributions of altitude at the time of the first RA, firstly for all RA sequence types, and then for each individual RA sequence type (for sequences that were recorded at least 30 times).

Table 3-8 on page 29 shows the distribution of RA sequences in altitude layers, as well as the minimum and maximum recorded altitudes for each sequence type. The total distribution (for all first RAs) is also shown.

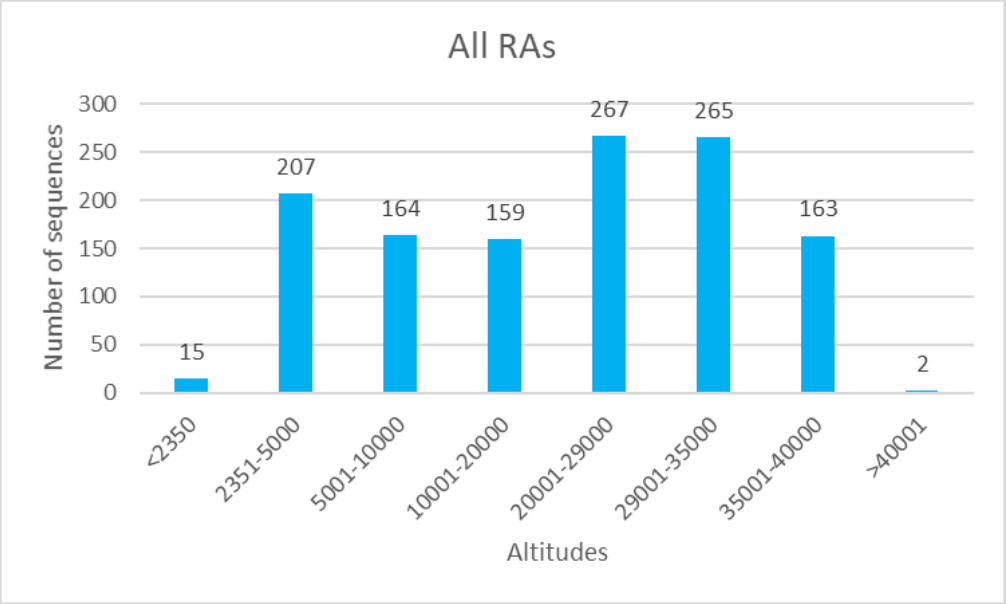

Figure 3-10: First RA altitude distribution for all RA sequence types.

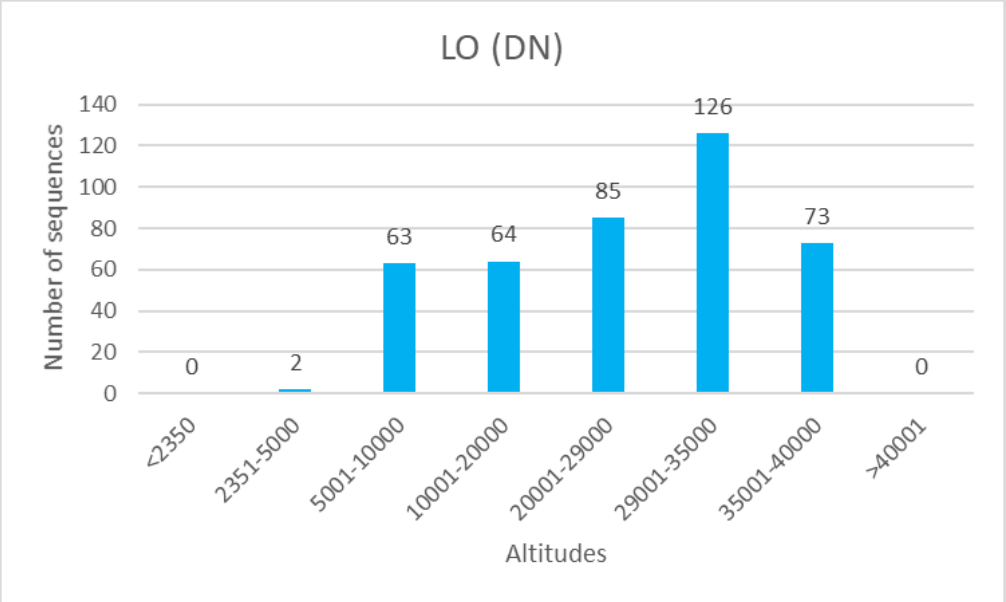

Figure 3-11: First RA altitude distribution for LO (DN) RA sequence type.

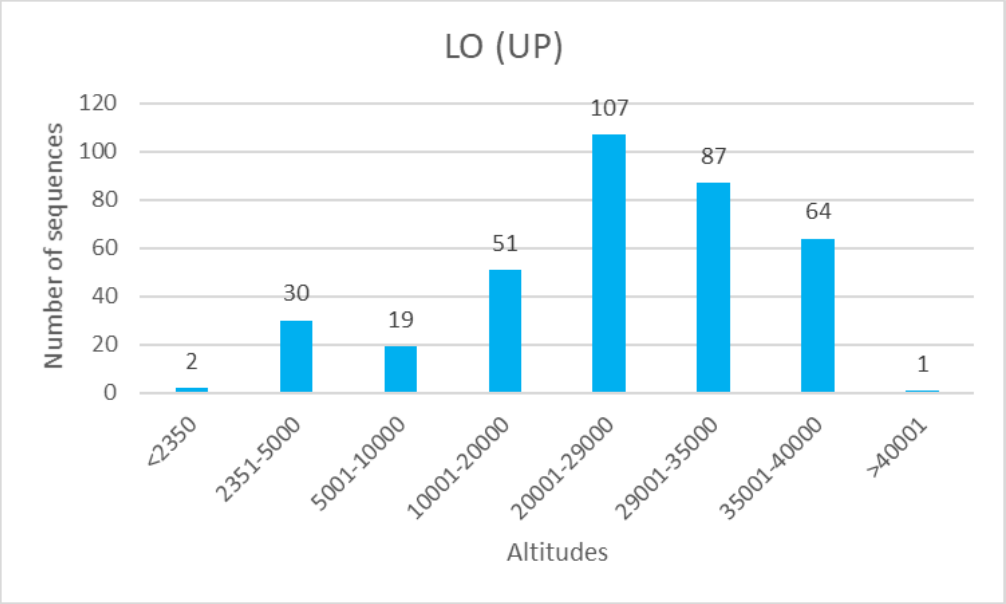

Figure 3-12: First RA altitude distribution for LO (UP) RA sequence type.

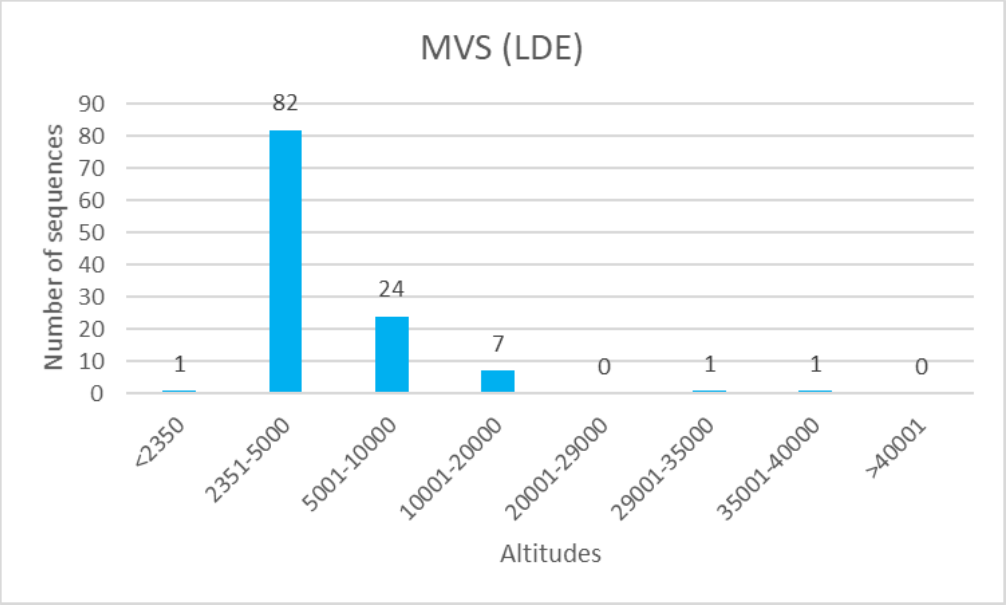

Figure 3-13: First RA altitude distribution for MVS (LDE) RA sequence type.

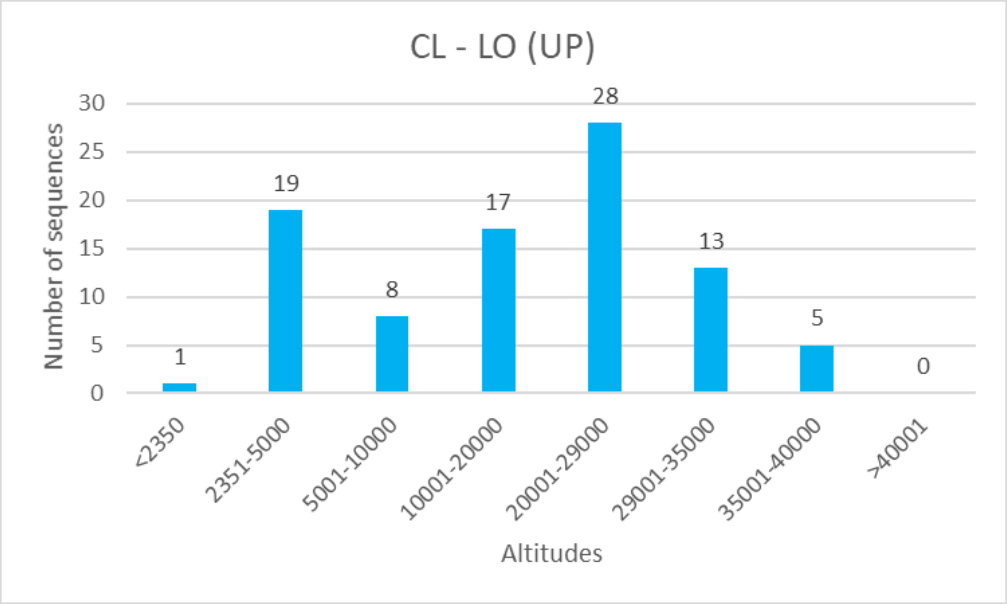

Figure 3-14: First RA altitude distribution for CL – LO (UP) RA sequence type.

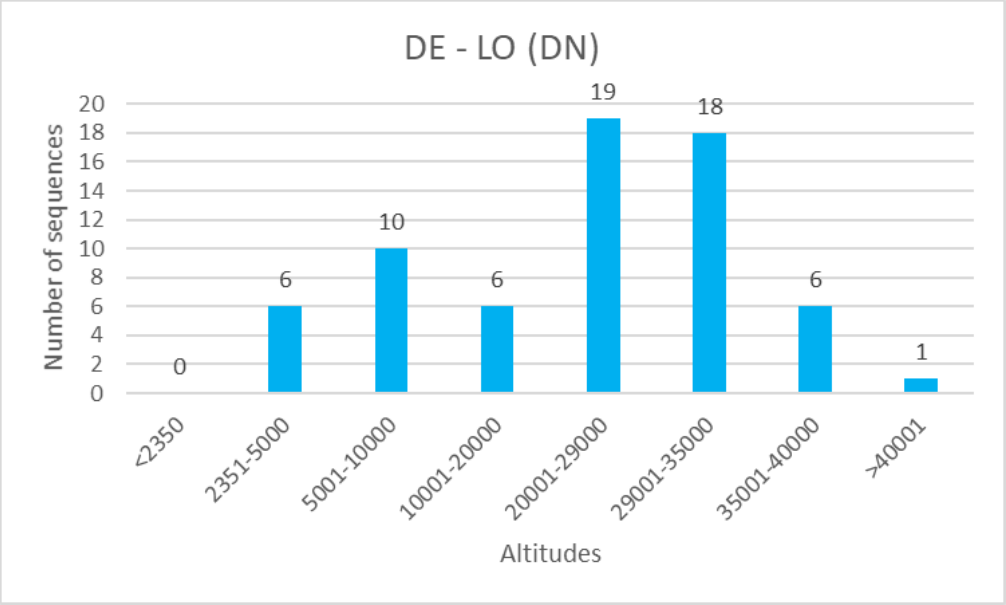

Figure 3-15: First RA altitude distribution for DE – LO (DN) RA sequence type.

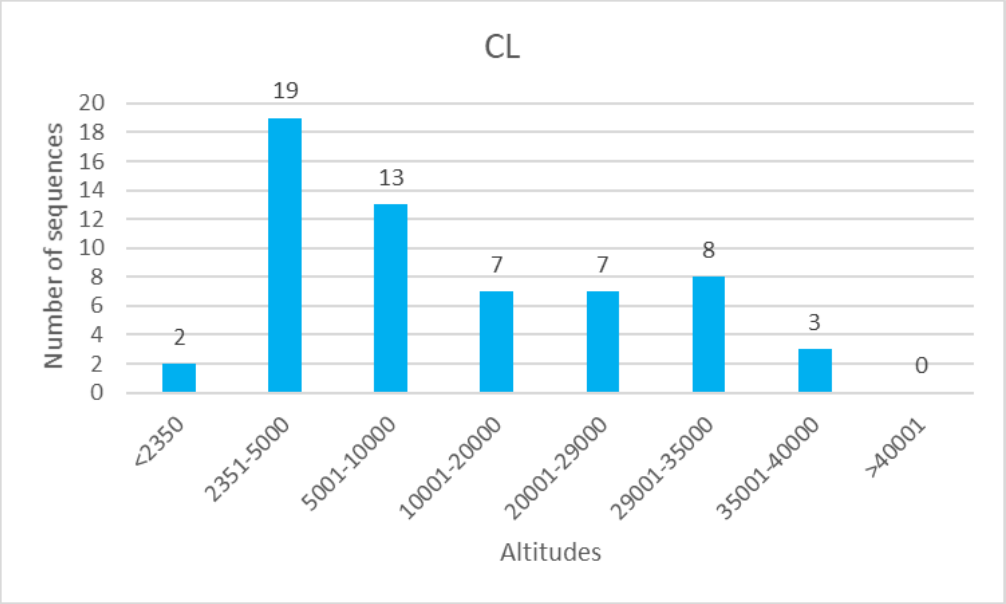

Figure 3-16: First RA altitude distribution for CL RA sequence type.

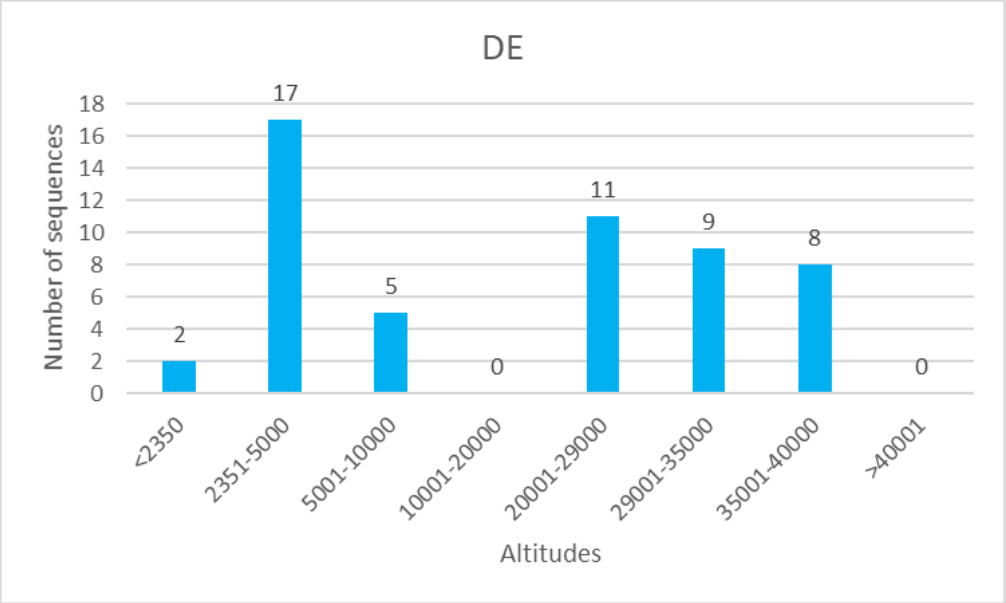

Figure 3-17: First RA altitude distribution for DE RA sequence type.

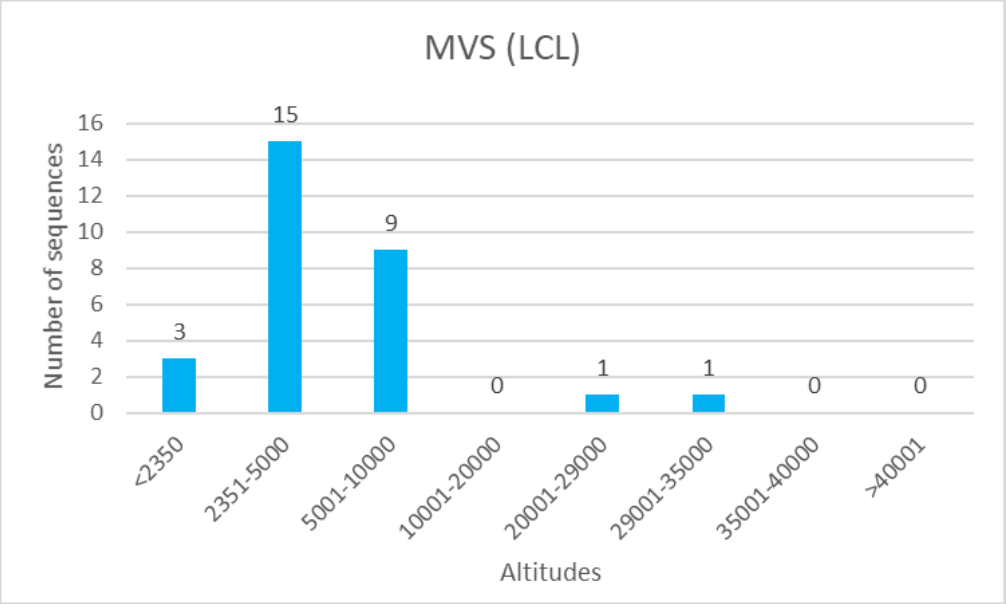

Figure 3-18: First RA altitude distribution for MVS (LCL) RA sequence type.

Table 3-8: Distribution of altitudes (in feet) of first RAs in each sequence type

RA sequence	<2350	2351-5000	5001-10000	10001-20000	20001-29000	29001-35000	35001-40000	>40001	Min. Alt.	Max. Alt.
LO (DN)	0	2	63	64	85	126	73	0	2375	40000
LO (UP)	2	30	19	51	107	87	64	1	1975	41000
MVS (LDE)	1	82	24	7	0	1	1	0	2100	37000
CL-LO (UP)	1	19	8	17	28	13	5	0	2175	37975
DE-LO (DN)	0	6	10	6	19	18	6	1	2700	40025
CL	2	19	13	7	7	8	3	0	1925	38000
DE	2	17	5	0	11	9	8	0	2200	39000
MVS (LCL)	4	15	9	0	1	1	0	0	2200	33975
LO (UP)-CL	0	1	3	4	2	0	0	0	3400	25025
LO (DN)-DE-LO (DN)	0	0	0	1	2	2	1	0	19975	35275
MVS (LDE)-LO (UP)	1	4	0	0	1	0	0	0	2175	21075
MVS (LCL)-LO (DN)	1	2	1	0	0	0	0	0	2075	10000
LO (UP)-CL-LO (DELD)	0	1	0	0	2	0	0	0	4525	29000
DE-MaVS (CL)	0	2	1	0	0	0	0	0	2425	5225
MVS (LCL)-DE	0	1	1	0	0	0	0	0	4000	8000
LO (DN)-DE	0	0	1	0	1	0	0	0	5400	22875
XDE-LO (DN)	1	0	0	0	0	0	1	0	2200	38550
CL-RDE	0	0	2	0	0	0	0	0	6750	8925
CL-LO (UP)-CL	0	0	0	0	1	0	0	0	22000	22000
MVS (LDE)-CL-LO (UP)	0	1	0	0	0	0	0	0	3950	3950
DE-MaVS (CL)-LO (UP)	0	0	1	0	0	0	0	0	5400	5400
DE-RCL-LO (UP)	0	0	1	0	0	0	0	0	6000	6000
CL-RDE-LO (DN)	0	1	0	0	0	0	0	0	2900	2900

RA sequence	<2350	2351-5000	5001-10000	10001-20000	20001-29000	29001-35000	35001-40000	>40001	Min. Alt.	Max. Alt.
LO (UP)-CL-MaVS (DE)	0	1	0	0	0	0	0	0	3300	3300
DE-IDE-RCL-LO (UP)	0	0	1	0	0	0	0	0	10000	10000
MVS (LDE)-CL	0	0	0	1	0	0	0	0	12000	12000
CL- ICL	0	0	1	0	0	0	0	0	10000	10000
MaVS (CL)-LO (UP)	0	0	0	1	0	0	0	0	15575	15575
MaVS (DE)-LO (DN)	0	1	0	0	0	0	0	0	2800	2800
DE-RCL	0	0	0	0	0	0	1	0	39000	39000
XCL	0	1	0	0	0	0	0	0	4400	4400
MaVS (DE)	0	1	0	0	0	0	0	0	4800	4800
Total (all RAs):	**15**	**207**	**164**	**159**	**267**	**265**	**163**	**2**	**1925**	**41000**

3.6 Coordinated and uncoordinated encounters and intruder equipage

RAs can be generated only against intruders equipped with an altitude reporting transponder (Mode A/C or Mode S). If the intruder is also equipped with TCAS II and considers the own aircraft as a threat, RAs will be coordinated via a Mode S datalink. Table 3-9 below shows the number of coordinated and uncoordinated encounters and encounters by the intruder equipage.

There were no multi-threat[14] encounters recorded.

Table 3-9: Uncoordinated and coordinated encounters

Encounters with valid RA	1072
Uncoordinated encounters	902
Coordinated encounters	170
Encounters against Mode S equipped intruders	1031
Encounters against Mode A/C equipped intruders	41
Multi-threat encounters	0

3.7 Coordinated encounters: own RA vs. intruder's RA

Table 3-10 below shows the relationship between own and intruder's 1st RAs for the 170 coordinated encounters.

Table 3-10: Own 1st RA vs. intruder's 1st RA

		Intruder's 1st RA					
		CL	DE	LO (UP)	LO (DN)	MVS (LDE)	MVS (LCL)
Own aircraft 1st RA	CL	–	9	–	20	–	–
	DE	15	–	18	–	–	–
	LO (UP)	–	14	–	32	–	2
	LO (DN)	23	–	30	–	2	–
	MVS (LDE)	–	–	–	2	1	1
	MVS (LCL)	–	–	1	–	–	–

3.8 Coordinated encounters: altitude distribution

Table 3-11 and Figure 3-19 below show the distribution of altitudes in coordinated encounters.

[14] Encounter where the own aircraft receives RAs against two or more threats simultaneously.

Table 3-11: Altitude distribution in coordinated encounters

Altitude [ft]	Number	Percentage
<2350	0	0.0%
2351 – 5000	7	4.1%
5001 – 10000	20	11.8%
10001 – 20000	41	24.1%
20001 – 29000	47	27.6%
29001 – 35000	40	23.5%
35001 – 40000	14	8.2%
>40001	1	0.6%
Total:	**170**	**100.0%**

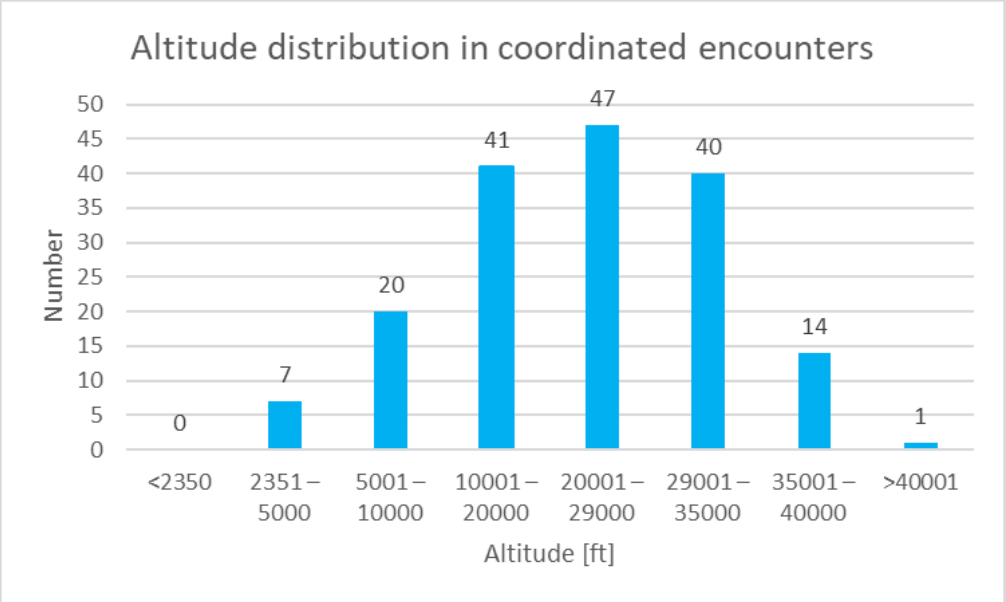

Figure 3-19: Altitude distribution in coordinated encounters

3.9 Encounters against Mode A/C intruders: own aircraft 1st RA

Table 3-12 below lists the 1st RA generated in all the 41 encounters against Mode A/C intruders.

Table 3-12: Own aircraft RA against Mode A/C intruders

Own 1st RA	Number
CL	8
DE	7
LO (UP)	11
LO (DN)	3
MVS (LDE)	7
MVS (LCL)	5

3.10 Uncoordinated encounters: altitude distribution

Table 3-13 and Figure 3-20 below shows the distribution of altitudes in uncoordinated (i.e. encounters against Mode A/C intruders).

Table 3-13: Altitude distribution in encounters against Mode A/C intruders

Altitude [ft]	Number	Percentage
<2350	6	14.6%
2351 – 5000	12	29.3%
5001 – 10000	9	22.0%
10001 – 20000	12	29.3%
20001 – 29000	1	2.4%
29001 – 35000	0	0.0%
35001 – 40000	1	2.4%
>40001	0	0.0%
Total:	**41**	**100.0%**

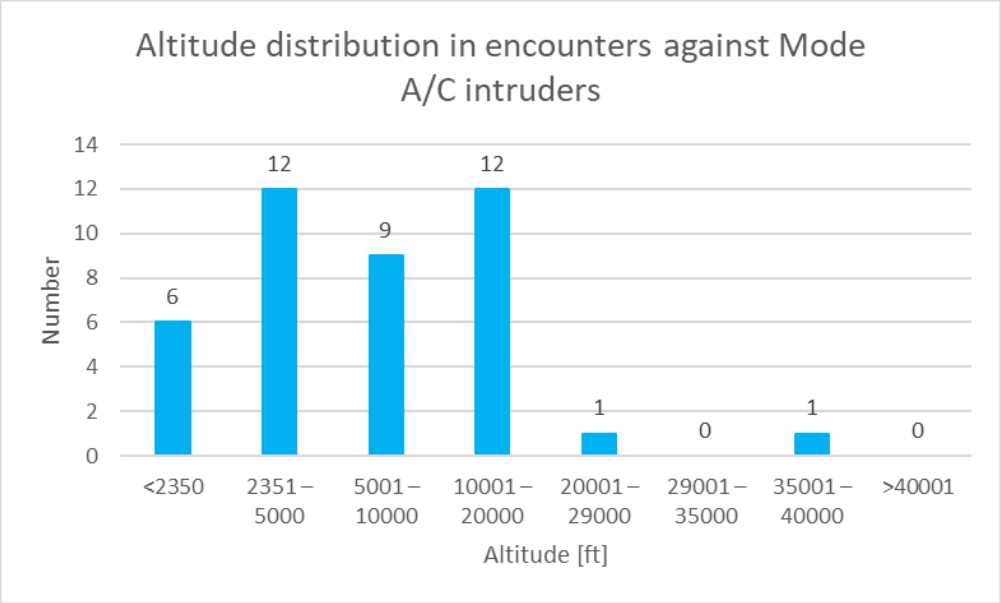

Figure 3-20: Altitude distribution in encounters against Mode A/C intruders

3.11 Encounter distribution by time of day

Table 3-14 and Figure 3-21 below show the distribution of encounters by time of day (in 2-hour intervals). The time is UTC (Coordinated Universal Time) – the local time at the data collection locations was UTC+2 and UTC+1 (in summer and winter respectively).

Table 3-14: Encounter distribution by time of day

Time from	Time to	Encounters	Percentage
00:00:01	02:00:00	2	0.2%
02:00:01	04:00:00	2	0.2%
04:00:01	06:00:00	40	3.7%
06:00:01	08:00:00	109	10.2%
08:00:01	10:00:00	187	17.4%
10:00:01	12:00:00	152	14.2%
12:00:01	14:00:00	176	16.4%
14:00:01	16:00:00	141	13.2%
16:00:01	18:00:00	146	13.6%
18:00:01	20:00:00	72	6.7%
20:00:01	22:00:00	40	3.7%
22:00:01	00:00:00	5	0.5%
	Total:	**1072**	**100.0%**

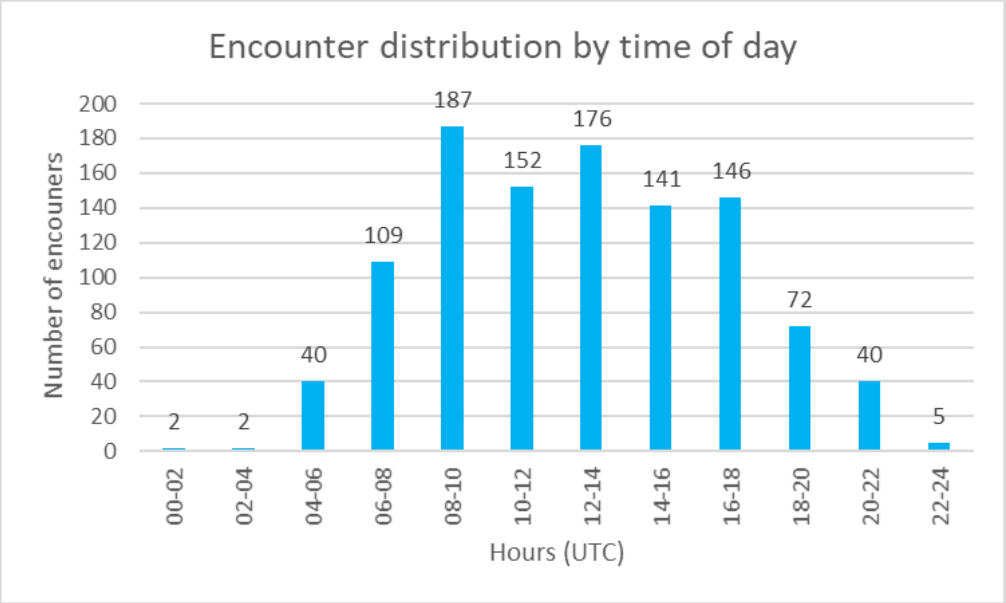

Figure 3-21: Encounter distribution by time of day

3.12 Encounter distribution by day of week

Table 3-15 and Figure 3-22 below show the distribution of encounters by day of week.

Table 3-15: Encounter distribution by day of week

Day of week	Number of encounters	Percentage
Monday	141	13.2%
Tuesday	147	13.7%
Wednesday	172	16.0%
Thursday	188	17.5%
Friday	180	16.8%
Saturday	119	11.1%
Sunday	125	11.7%
Total:	**1072**	**100.0%**

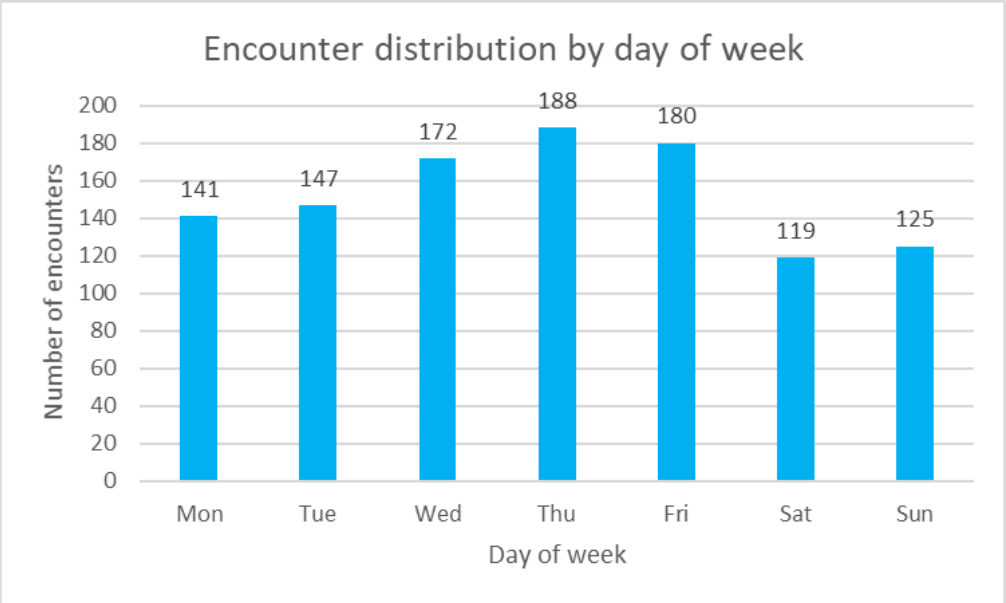

Figure 3-22: Encounter distribution by day of week

3.13 Encounter distribution by month

Table 3-16 and Figure 3-23 below show the distribution of encounters by month.

Table 3-16: Encounter distribution by month

Month	Number of encounters	Percentage
January	51	4.8%
February	67	6.3%
March	79	7.4%
April	106	9.9%
May	112	10.4%
June	106	9.9%
July	140	13.1%
August	111	10.4%
September	112	10.4%
October	78	7.3%
November	56	5.2%
December	54	5.0%
Total:	**1072**	**100.0%**

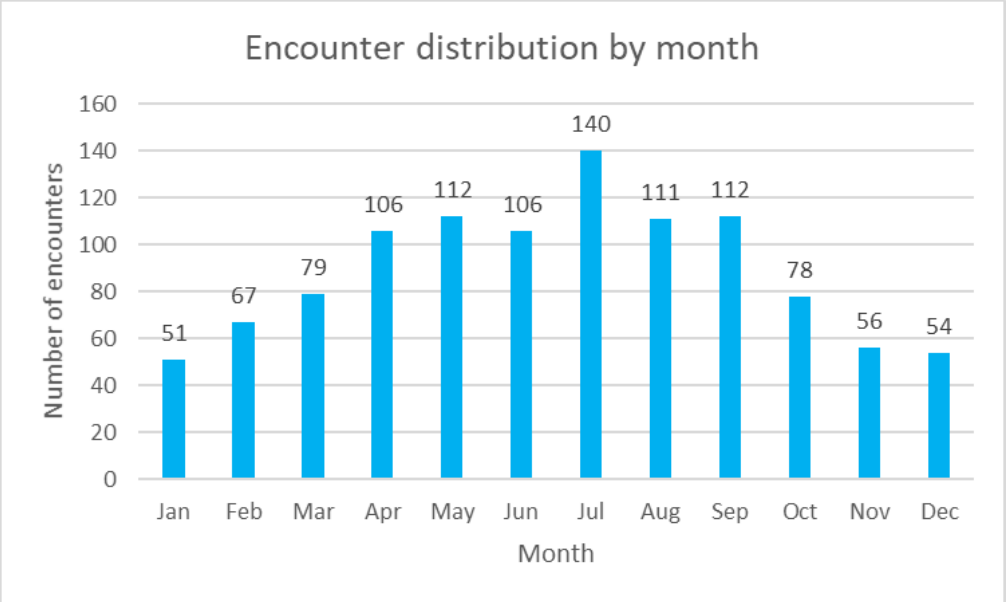

Figure 3-23: Encounter distribution by month

3.14 1st RA recorded by type

There were 1242 first RAs. The "first RA" is the initial RA generated in an encounter. Table 3-17 below shows the numbers of first RA received for each RA type.

Table 3-17: 1st RA recorded by type

1st RA	Number	Percentage
LO (DN)	421	33.8%
LO (UP)	375	30.2%
CL	155	12.5%
DE	125	10.1%
MVS (LDE)	124	10.0%
MVS (LCL)	36	2.9%
XDE	2	0.2%
MaVS (DE)	2	0.2%
XCL	1	0.1%
MaVS (CL)	1	0.1%
Total:	**1242**	**100.0%**

3.15 2nd RA recorded by type

There were 209 second RAs. Table 3-18 below shows the numbers of second RAs issued for each RA type.

Table 3-18: 2nd RA recorded by type

2nd RA	Number	Percentage
LO (UP)	99	47.4%
LO (DN)	73	34.9%
CL	16	7.7%
DE	10	4.8%
MaVS (CL)	4	1.9%
RDE	3	1.4%
RCL	2	1.0%
ICL	1	0.5%
IDE	1	0.5%
Total:	**209**	**100.0%**

3.16 3rd RA recorded by type

There were 16 third RAs. Table 3-19 below shows the numbers of third RAs received for each RA type.

Table 3-19: 3rd RA recorded by type

3rd RA	Number	Percentage
LO (DN)	7	43.8%
LO (UP)	6	37.5%
MaVS (DE)	1	6.3%
CL	1	6.3%
RCL	1	6.3%
Total:	**16**	**100.0%**

3.17 4th RA recorded by type

There was only one fourth RA recorded. It was a LO (UP) RA.

3.18 Duration of individual 1st RAs

The duration of individual 1st RAs are shown in Table 3-20 on page 39. Although the values presented in Table 3-20 can also be derived from Table 3-5 (Total duration of RA sequences) on page 16, shows the values for individual RAs rather than sequences is provided for the Reader's convenience.

3.19 Vertical Separation & Horizontal Separation at 1st RA

Table 3-21 on page 40 shows the values of vertical separation and horizontal separation at the time of 1st RA. The data is presented for all 1242 1st RAs, as in coordinated encounters the RAs are not necessarily generated at the same time.

3.20 Vertical Miss Distance & Horizontal Miss Distance at Closest Point of Approach

Table 3-22 on page 41 shows the values of Vertical Miss Distance (VMD) and Horizontal Miss Distance (HMD) at the time of Closest Point of Approach (CPA) for all 1072 encounters.

Table 3-20: Duration of individual 1st RAs

	Duration [seconds]															
1st RA	<=4	5-8	9-12	13-16	17-20	21-24	25-28	29-32	33-36	37-40	41-44	45-48	49-52	53-56	57-60	>61
CL	34	55	41	17	5	1	0	1	0	0	0	0	0	0	0	1
DE	27	33	39	18	3	1	1	0	1	1	0	0	0	0	0	1
XCL	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XDE	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LO (UP)	58	36	35	24	24	30	31	36	45	39	7	0	1	0	1	8
LO (DN)	39	38	31	26	30	54	47	57	53	38	5	1	0	0	0	2
MaVS (CL)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MaVS (DE)	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
MVS (LDE)	52	14	9	10	10	16	6	3	2	2	0	0	0	0	0	0
MVS (LCL)	11	4	5	5	3	6	1	1	0	0	0	0	0	0	0	0

Table 3-21: Vertical Separation & Horizontal Separation at 1st RA

		Horizontal Separation [NM]																		
		<= 0.2	0.21 – 0.4	0.41 – 0.6	0.61 – 0.8	0.81 – 1.0	1.01 – 1.2	1.21 – 1.4	1.41 – 1.6	1.61 – 1.8	1.81 – 2.0	2.01 – 2.5	2.51 – 3.0	3.01 – 3.5	3.51 – 4.0	4.01 – 4.5	4.51 – 5.0	5.01 – 6.0	6.01 – 7.0	7.01 – 8.0	>= 8.01
Vertical Separation [ft]	<=200	0	2	7	6	12	4	6	0	3	3	2	3	0	2	0	0	1	2	4	0
	201 – 400	0	1	3	3	4	3	5	4	2	3	3	2	3	1	0	1	1	2	0	0
	401 – 600	4	6	16	30	28	34	17	15	12	3	14	2	6	2	1	0	5	3	6	2
	601 – 800	3	3	4	7	3	8	5	0	1	2	3	0	0	0	1	0	0	0	3	1
	801 – 1000	0	0	2	1	0	1	2	6	4	2	4	5	0	2	7	2	6	2	2	2
	1001 – 1200	1	1	2	2	8	6	11	8	8	9	18	24	15	14	12	10	20	19	19	8
	1201 – 1400	1	0	0	1	1	1	5	6	2	3	14	17	15	17	11	13	24	26	17	5
	1401 – 1600	0	0	3	3	3	4	0	1	2	3	7	3	11	6	10	6	24	22	14	6
	1601 – 1800	0	1	1	2	3	0	1	3	1	2	2	8	9	7	4	8	14	13	7	0
	1801 – 2000	0	0	1	0	0	0	1	1	3	0	7	8	9	15	6	12	5	8	9	4
	2001 – 2500	0	0	0	2	2	0	4	4	0	2	2	11	12	8	6	4	29	8	7	3
	2501 – 3000	0	2	0	0	0	0	0	0	0	2	5	0	3	1	3	2	5	4	1	2
	3001 – 3500	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	1
	3501 – 4000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
	>=4001	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	1	0	1	1

Table 3-22: VMD & HMD at CPA

		HMD [NM]																		
		<= 0.2	0.21 – 0.4	0.41 – 0.6	0.61 – 0.8	0.81 – 1.0	1.01 – 1.2	1.21 – 1.4	1.41 – 1.6	1.61 – 1.8	1.81 – 2.0	2.01 – 2.5	2.51 – 3.0	3.01 – 3.5	3.51 – 4.0	4.01 – 4.5	4.51 – 5.0	5.01 – 6.0	6.01 – 7.0	7.01 – 8.0	>= 8.01
VMD [ft]	<=200	3	2	6	2	1	1	3	3	1	1	4	1	0	0	0	0	0	0	0	0
	201 – 400	4	3	8	4	5	6	2	0	1	2	1	0	1	0	0	0	0	0	0	0
	401 – 600	7	19	20	14	15	17	10	13	8	3	8	1	2	0	1	1	0	0	0	0
	601 – 800	12	3	10	8	10	8	6	5	5	2	4	2	3	0	0	0	0	0	0	0
	801 – 1000	10	12	8	7	11	8	7	6	3	2	6	3	0	0	0	0	0	0	0	0
	1001 – 1200	27	25	28	20	21	20	19	10	11	4	11	2	2	0	0	2	0	0	0	0
	1201 – 1400	16	32	15	18	15	15	13	2	7	8	6	3	0	0	1	0	0	0	0	0
	1401 – 1600	12	16	10	15	7	14	10	4	2	2	7	1	2	2	0	0	0	0	0	0
	1601 – 1800	8	12	11	8	10	4	8	5	4	1	3	0	0	0	0	1	0	0	0	0
	1801 – 2000	9	15	12	7	7	8	2	4	2	0	6	0	1	0	0	0	0	0	0	0
	2001 – 2500	8	12	4	8	11	5	7	4	3	1	4	2	2	0	0	0	0	0	0	0
	2501 – 3000	0	2	4	4	1	3	1	0	1	0	2	1	0	0	0	0	0	0	0	0
	3001 – 3500	1	2	1	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	3501 – 4000	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	>=4001	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.21 Elapsed time between 1st RA and CPA

Table 3-23 and Figure 3-24 below show the elapsed time between the 1st RA and CPA. Nominally, it is expected that an RA will get generated between 15 and 35 seconds before the CPA. While it was the case in the majority of the encounters, in some cases the 1st RA was generated either before the CPA or well after it. That may legitimately happen in certain geometries; however, the numbers seen here may indicate that in some of the cases the collected data was inaccurate or has been corrupted (see also Section 2.2 - Data limitations and accuracy on page 9).

Table 3-23: Elapsed time between 1st RA and CPA

Elapsed time [s]	Number	Percentage
<= -1	46	4.3%
0	12	1.1%
1-4	39	3.6%
5-7	64	6.0%
8-11	122	11.4%
12-16	123	11.5%
17-20	144	13.4%
21-24	130	12.1%
25-28	136	12.7%
29-32	150	14.0%
33-36	69	6.4%
37-40	4	0.4%
41-44	1	0.1%
45-48	4	0.4%
49-52	1	0.1%
53-56	2	0.2%
57-60	0	0.0%
>= 61	25	2.3%
Total:	**1072**	**100.0%**

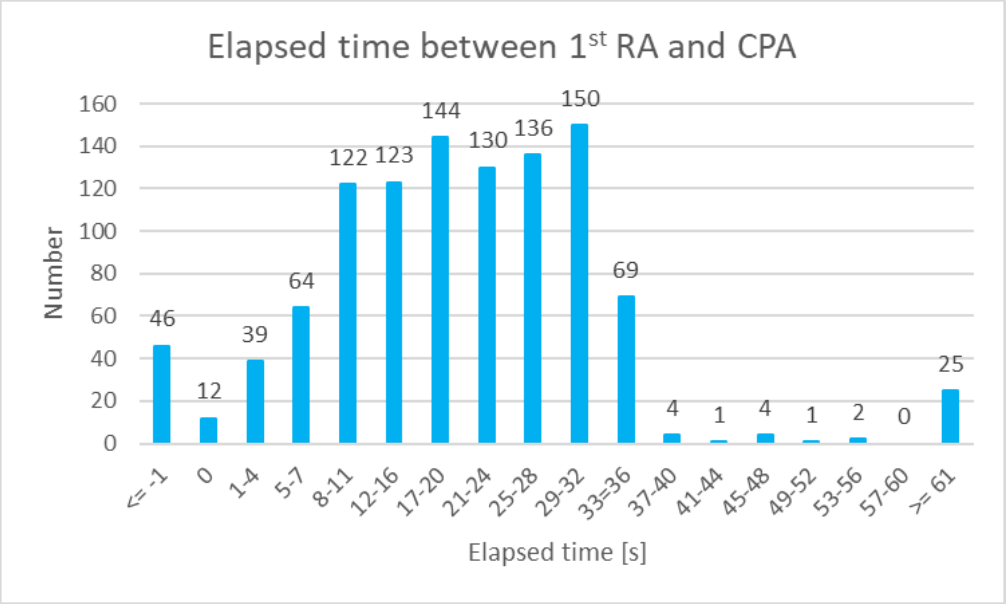

Figure 3-24: Elapsed time between 1st RA and CPA

3.22 Vertical rates 8 seconds before the RA

Table 3-26 on page 45 shows the distribution of vertical rates (in 500-foot increments) 8 seconds before the RA (by RA type). The lowest, average, median and highest vertical rates 8 seconds before the RA are presented in Table 3-24 below.

Table 3-24: Lowest, average, median and highest vertical rates 8 seconds before RA

	Vertical rate [ft/min.]			
RA type	Lowest	Average	Median	Highest
CL	-3000	-546	-600	2625
XCL	675	675	675	675
DE	-1725	427	150	3000
XDE	-1538	-638	-638	263
LO (UP)	-8700	-2092	-1988	525
LO (DN)	-38	2229	2138	5363
MaVS (CL)	1875	1875	1875	1875
MaVS (DE)	-2513	-2119	-2119	-1725
MVS (LDE)	-1988	-86	0	1463
MVS (LCL)	-1088	218	0	2063

3.23 Vertical rates at the RA

The lowest, average, median and highest vertical rates at the time of RA are presented in Table 3-25 below. Table 3-27 on page 46 shows the distribution of vertical rates (in 500-foot increments) at the time of RA (by RA type).

Table 3-25: Lowest, average, median and highest vertical rates at the RA

	Vertical rate [ft/min.]			
RA type	Lowest	Average	Median	Highest
CL	-1725	81	38	2250
XCL	1200	1200	1200	1200
DE	-2325	-158	-263	3638
XDE	-1538	-844	-844	-150
LO (UP)	-10500	-1429	-1238	2025
LO (DN)	-150	1551	1463	5250
MaVS (CL)	1875	1875	1875	1875
MaVS (DE)	-1950	-1800	-1800	-1650
MVS (LDE)	-1425	-18	0	1875
MVS (LCL)	-975	77	0	1463

Table 3-26: Vertical rate 8 sec. before the RA

		Vertical rate [ft/min.]																	
		<= -3501	-3001 – -3500	-2501 – -3000	-2001 – -2500	-1501 – -2000	-1001 – -1500	-501 – -1000	-1 – -500	0	1 – 500	501 – 1000	1001 – 1500	1501 – 2000	2001 – 2500	2501 – 3000	3001 – 3500	>= 3501	NA*	Total
RA type	CL	0	0	2	1	11	30	42	13	25	22	3	3	1	0	1	0	0	1	**155**
	XCL	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**1**
	DE	0	0	0	0	1	5	11	18	21	9	29	20	5	1	5	0	0	0	**125**
	XDE	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
	LO (UP)	40	29	55	60	57	71	44	12	2	0	1	0	0	0	0	0	0	4	**375**
	LO (DN)	0	0	0	0	0	0	0	1	0	3	26	61	87	105	69	29	40	0	**421**
	MaVS (CL)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	MaVS (DE)	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
	MVS (LDE)	0	0	0	0	3	2	7	26	48	37	0	1	0	0	0	0	0	0	**124**
	MVS (LCL)	0	0	0	0	0	2	1	6	11	9	1	3	2	1	0	0	0	0	**36**
	Total:	**40**	**29**	**58**	**61**	**74**	**110**	**105**	**76**	**107**	**81**	**61**	**88**	**96**	**107**	**75**	**29**	**40**	**5**	**1242**

*) The Vertical Rate has not been recorded.

Table 3-27: Vertical rates at the RA

		Vertical rate [ft/min.]																	
		<= -3501	-3001 – -3500	-2501 – -3000	-2001 – -2500	-1501 – -2000	-1001 – -1500	-501 – -1000	-1 – -500	0	1 – 500	501 – 1000	1001 – 1500	1501 – 2000	2001 – 2500	2501 – 3000	3001 – 3500	>= 3501	Total
RA type	CL	0	0	0	0	3	7	17	34	15	40	20	15	3	1	0	0	0	**155**
	XCL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	DE	0	0	0	2	2	16	20	39	7	21	7	5	2	1	1	0	2	**125**
	XDE	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	**2**
	LO (UP)	12	10	28	45	53	85	72	60	2	6	1	0	0	1	0	0	0	**375**
	LO (DN)	0	0	0	0	0	0	0	4	2	39	72	113	85	53	22	16	15	**421**
	MaVS (CL)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
	MaVS (DE)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	**2**
	MVS (LDE)	0	0	0	0	0	4	2	32	42	39	4	0	1	0	0	0	0	**124**
	MVS (LCL)	0	0	0	0	0	0	2	14	9	5	2	4	0	0	0	0	0	**36**
	Total:	**12**	**10**	**28**	**47**	**61**	**112**	**113**	**184**	**77**	**150**	**106**	**138**	**91**	**57**	**23**	**16**	**17**	**1242**

3.24 Vertical rates at the RA – altitude distribution

Table 3-28 below shows the distribution of vertical rates at the RA by altitude.

Table 3-28: Vertical rates at the RA – altitude distribution

		Altitude [ft]							
		<= 2350	2351 – 5000	5001 – 10000	10001 – 20000	20001 – 29000	29001 – 35000	35001 – 40000	>= 40001
Vertical rate [ft/min.]	-3501 – -15000	0	0	1	1	6	2	2	0
	-3001 – -3500	0	0	0	2	3	3	2	0
	-2501 – -3000	0	0	0	0	9	9	10	0
	-2001 – -2500	0	1	0	3	22	12	9	0
	-1501 – -2000	1	5	3	8	20	15	9	0
	-1001 – -1500	0	12	18	16	29	17	20	0
	-501 – -1000	1	21	13	18	22	23	14	1
	-1 – -500	5	60	18	19	33	33	15	1
	0	4	45	19	1	1	3	4	0
	1 – 500	1	45	19	14	35	27	9	0
	501 – 1000	2	7	14	14	23	31	15	0
	1001 – 1500	0	8	19	23	26	41	21	0
	1501 – 2000	0	0	14	19	18	26	14	0
	2001 – 2500	1	0	11	11	14	11	9	0
	2501 – 3000	0	1	4	4	4	5	5	0
	3001 – 3500	0	0	6	3	2	2	3	0
	3501 – 10000	0	2	5	3	0	5	2	0

4 Airborne data: Traffic and Resolution Advisories

TCAS data collected on the ground is subject to limitations mentioned in Section 2.2 on page 9. Additionally, some TCAS events (for instance Traffic Advisories) cannot be recorded on the ground as they are not downlinked. To expand on the data set obtained from radar recordings and analysed in Section 3 above, EUROCONTROL has obtained from a number of airlines their TCAS statistics collected through the Flight Data Monitoring (FDM) scheme.

The airline results have been aggregated in Table 4-1 below to provide information on the range of TA and RA frequency (per flight leg and per flight hour) as well as the TA:RA ratio. The data is presented as a function of the operation type short- & medium-haul (single aisle) vs. long-haul (wide body) as the number of alerts in each type of the fleet will vary due to different exposure to situations that are likely to result in TCAS alerts.

Table 4-1: TA and RA airborne data

Fleet (operations) type	Flight legs/TA [range]	Flight legs/RA [range]	TA:RA ratio [range]	Flight hours/RA
Short- & medium haul (single aisle)	10 – 16	2475 – 3603	164 – 238	3400 – 6691
Long haul (wide body)	10 – 12	1047 – 1053	95 – 120	N/A

5 Impact of the COVID-related traffic reduction

The reduction in air traffic due to the COVID-related restrictions will certainly have an impact on the frequency of TCAS alerts, as due the lower traffic density and the lower number of flights, aircraft will be less likely to be in conflict. Initial monitoring data indicates that the number of RAs dropped to 25-30% of the pre-COVID situation. However, at the time of writing there is no information available regarding other statistical aspects mentioned in this document.

6 Abbreviations, Glossary and References

6.1 Abbreviations

For RA abbreviations refer to Table 2-1 on page 11.

Table 6-1: Other abbreviations

Abbreviation	Meaning
ACAS	Airborne Collision Avoidance System
ATC	Air Traffic Control
CPA	Closest Point of Approach
FDM	Flight Data Monitoring
HMD	Horizontal Miss Distance
IATA	International Air Transport Association
RA	Resolution Advisory
TA	Traffic Advisory
TCAS	Traffic Alert and Collision Avoidance System
VMD	Vertical Miss Distance
UTC	Coordinated Universal Time

6.2 Glossary of Terms

For more definitions and information refer to the EUROCONTROL ACAS Guide.

Closest Point of Approach (CPA) – The occurrence of minimum (slant) range between own ACAS aircraft and the intruder. Range at CPA is the smallest range between the two aircraft and time at CPA is the time at which it occurs.

Crossing RA – An RA during which the own aircraft is expected to cross the altitude of the intruder before closest approach.

Coordinated encounter – an encounter in which two TCAS II equipped aircraft simultaneously receive RAs against each other.

Encounter – a situation when two or more aircraft are in proximity, so an RA gets trigger on at least one of them.

Horizontal Miss Distance (HMD) – the horizontal range between two aircraft at the Closest Point of Approach.

Intruder (aircraft) – An aircraft within the surveillance range of ACAS II for which ACAS II has an established track.

Multi-threat encounter – encounter where the own aircraft receives RAs against two or more threats simultaneously.

Preventive advisory – A resolution advisory that instructs the pilot to avoid certain deviations from current vertical rate, for example a Monitor Vertical Speed (do not climb) RA when the aircraft is level.

Reversed sense RA – an RA type, which has its sense reversed in the opposite direction to the previous one.

Sequence (RA sequence) – an RA or a number of subsequent RAs generated on one aircraft during an encounter. An RA sequence ends with Clear of Conflict or RA termination.

Strengthening RAs – an RA type, which increases the strength of the previously issued RA. For example, an initial positive RA (which requires either climb or descend) can be strengthened to either Increase Climb or Increase Decent RAs.

Threat (aircraft) – An intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near collision course with own aircraft.

Vertical Miss Distance (VMD) – the relative altitude between own and intruder aircraft at closest point of approach.

Weakening RA – an RA type generated in order to reduce vertical deviation from initial path induced by an initial RA.

6.3 References

IATA/EUROCONTROL Guidance Material on Performance assessment of pilot compliance to Traffic Alert and Collision Avoidance System (TCAS) using Flight Data Monitoring (FDM), November 2020.

EUROCONTROL ACAS Guide, December 2017.

TCAS RA not Followed, Network Manager Operational Safety Study, EUROCONTROL, September 2017.

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