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Asia and Pacific Office

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Agenda Item 5: Presentations – State / Industry / ICAO

MAPPING OF LHD/LLE/LLD CATEGORIES TO ICAO CAST TAXONOMY

(Presented by the Secretariat)

SUMMARY

This working paper presents the mapping of the categories of RASMAG data to the ICAO CAST taxonomy of aviation occurrence categories document to better understanding the data collected by RASMAG and the relevance to Mid Air Collision (MAC) risk.

1. INTRODUCTION

1.1 As presented at the Tenth Meeting of the Air Traffic Management Sub-Group of APANPIRG ATM/SG10, 17-21 October 2021), Task # 2 of the RASG-APAC 2021/2022 Yearly and Standing Work Programme was highlighted. There was ongoing discussion by RASG and the Asia/Pacific Regional Aviation Safety Team (APRAST) on whether Mid-Air Collision (MAC) be considered as a High Risk Category event in the Asia Pacific Regional Aviation Safety Plan (AP-RASP), with data to be aligned with the Global Aviation Safety Plan (GASP) priorities. Collaboration with the Regional Airspace Safety Monitoring Advisory Group (RASMAG) would be needed to facilitate a thorough study and data analysis of MAC risk by the Asia/Pacific Safety Reporting and Programme Working Group (AP-SRP WG), with the results to be presented to APRAST.

1.2 In order to better understanding the data collected by RASMAG and the relevance to MAC risk, a mapping of the categories of RASMAG data to the taxonomy of aviation occurrence categories in a document jointly developed by International Civil Aviation Organization (ICAO) and the Commercial Aviation Safety Team (CAST), which jointly chartered the CAST/ICAO Common Taxonomy Team (CICTT), was conducted.

1.3 In this document, a common taxonomies and definitions for aviation accident and incident reporting systems was developed to improve the aviation community's capacity to focus on common safety issues. CICTT includes experts from air carriers, aircraft manufacturers, engine manufacturers, pilot associations, regulatory authorities, transportation safety boards, and ICAO, and members from Canada, the European Union, France, Italy, Japan, the Netherlands, the United Kingdom, and the United States. CICTT is co-chaired by a representative from ICAO and a representative from CAST. Definitions of ICAO CAST taxonomy for occurrences are extracted and shown in **Appendix A**.

1.4 RASMAG monitors Large Height Deviation (LHD), Large Longitudinal Errors (LLE) and Large Lateral Deviation (LLD) and computes risk estimates based on the Collison Risk Model (CRM). The definitions of LHD, LLE & LLD are as follows:

a) Definition of LHD: A vertical deviation from an ATC assigned or coordinated altitude that results in an error of 300 ft or more. The deviation may be the result of human error, equipment malfunction or environmental factors such as turbulence, and should be reported in accordance with the LHD types.

b) Definition of LLDs – Any lateral deviation from the current flight plan that is greater than a regionally agreed value. Asia Pacific Region has agreed to the value of 10 NM.

c) Definition of LLE - Any unexpected change in longitudinal separation between an aircraft pair, or for an individual aircraft the difference between an estimate for a given fix and the actual time of arrival over that fix, as applicable. Additional information can be found in the **Table 1** below

Type of Error	*Category of Error*	*Criterion for Reporting*
Lateral Deviation	Individual-aircraft error	Any lateral deviation from the current flight plan track that is greater than a regionally agreed value pertinent to the applied separation minimum.
Longitudinal Deviation	Aircraft-pair (time-based separation applied)	Infringement of longitudinal separation standard based on routine position reports.
Longitudinal Deviation	Aircraft-pair (time-based separation applied)	Expected time between two aircraft varies by 2 minutes or more based on routine position reports.
Longitudinal Deviation	Individual-aircraft (time-based separation applied)	Pilot estimate varies by 2 minutes or more from that advised in a routine position report.
Longitudinal Deviation	Aircraft-pair (distance-based separation applied)	Infringement of longitudinal separation standard, based on ADS, radar measurement or special request for RNAV position report.
Longitudinal Deviation	Aircraft-pair (distance-based separation applied)	Expected distance between an aircraft pair varies by 6 NM or more, even if separation standard is not infringed, based on ADS, radar measurement or special request for RNAV position report.

Table 1: Definition of LLD & LLE

2. DISCUSSION

2.1 In RASMAG, LHD, LLE & LLD are tracked in various categories, LHDs are mainly reported by ANSPs and compiled by Regional Monitoring Agencies (RMAs) and LLDs/LLEs are compiled by En-route Monitoring Agencies (EMAs)

2.2 The categories of LHD/LLE/LLD have been developed and refined over the years to facilitate identification of contributing factors and to provide mitigations. (Full list of LHD categories (Cat A to M) can be found here: MAAR: Monitoring Agency for Asia Region (aerothai.co.th) and in Appendix B)

2.3 RASMAG assesses risk based on the collision risk model (CRM in terms of a probability value compared to the Target Level of Safety (TLS), which is defined as 5 x 10-9 fatal accidents per flight hour (fapfh). An LHD event is but one of the parameters in the risk estimation. Duration and flight levels crossed by the LHD are inputs for the CRM. Furthermore, the CRM models also take into account the design of the concerned airspace and one essential parameter includes the occupancy value (roughly translated to the number of aircraft in a certain airspace in a given time frame).

2.4 To put this into perspective, a certain LHD occurring in a “crowded” airspace may cause the risk to exceed the TLS value whereas the same LHD in a “not so crowded” airspace may not cause the risk to exceed the TLS. An example of a ”crowded” airspace is the AKARA corridor where a LHD of 9.25 seconds’ duration will cause the risk to exceed the TLS based on RASMAG/23 AKARA safety assessment, 2016 traffic sample data.

2.5 Amongst the various categories of LHD/LLE/LLD in APAC region, the highest category of LHD belongs to Category E: Coordination errors in ATC-to-ATC transfer of control responsibility as a result of human factors issues. Such LHDs occurs commonly between boundaries of airspace sectors or FIRs involved only a single aircraft. RASMAG also captures Category J & K LHDs involving TCAS RA events. For TCAS RA to be considered a LHD, the TCAS RA occurrence must have led to a vertical deviation of 300ft or more within the RVSM flight levels (FL290-FL410). Therefore, the RASMAG data would be a smaller dataset compared to a pure TCAS RA data.

For considerations

2.6 From RASMAG's perspective of the assessed risk, which is largely based on the CRM, all LHD/LLE/LLD could be viewed as precursors to MAC. CAST ICAO taxonomy shows clearly which events constitutes to MAC. However, it does not specifically say what events are considered pre cursors events. One may imply broadly that any LHD/LLE/LLD may lead to MAC.

2.7 Noting the unique nature of RASMAG data listed in the paragraph 2.3 - 2.5 and the numerous categories, an examination of the list of categories maybe worthwhile to determine the most relevant data required for MAC analysis. Therefore, a proposed mapping of categories of LHD, LLE & LLD to the ICAO CAST categories is shown in **Table 2** below to facilitate provision of relevant data required for MAC analysis.

LHD Code	LHD category	ICAO CAST Category	Remarks
A	Flight crew failing to climb/descend the aircraft as cleared	MAC, NAV	Classified as MAC if more than one aircraft involved
B	Flight crew climbing/descending without ATC clearance	MAC, NAV	Classified as MAC if more than one aircraft involved
C	Incorrect flight level provided due to incorrect operation or interpretation of airborne equipment (eg: incorrect operation of fully functional FMS, incorrect transcription of ATC clearance or re-clearance in FMS, flight plan followed rather than ATC clearance, original clearance followed instead of re-clearance)	MAC, NAV	Classified as MAC if more than one aircraft involved
D	ATC system loop error (eg: ATC issues incorrect flight level clearance or flight crew misunderstands flight level clearance message)	MAC, NAV, ATM	Classified as MAC if more than one aircraft involved
E	Coordination error in ATC to ATC transfer of control responsibility as a result of human factors issues (eg: late or non-existent coordination of flight level)	MAC, ATM	Classified as MAC if more than one aircraft involved

F	Coordination errors in ATC to ATC transfer of control responsibility as a result of equipment outage or technical issue	MAC, ATM	Classified as MAC if more than one aircraft involved
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level (eg: Pressurisation failure, engine failure)	SCF-NP, LOC-I	
H	Airborne equipment failure leading to unintentional or undetected change of flight level	MAC, SCF-NP, LOC-I	Classified as MAC if more than one aircraft involved
I	Turbulence or other weather related caused leading to unintentional or undetected change of flight level	TURB, WSTRW, ICE	
J	TCAS resolution advisory, Flight crew incorrectly climb or descend following the resolution advisory	MAC	Genuine TCAS/ACAS alerts
K	TCAS resolution advisory, Flight crew correctly climb or descend following the resolution advisory	MAC	Genuine TCAS/ACAS alerts
L	An aircraft was provided with RVSM separation is not RVSM approved (eg: flight plan indicating RVSM approval but aircraft not approved, ATC misinterpretation of flight plan)	N.A.	
M	Other		
LLE/LLD Code	LLE/LLD category	ICAO CAST Category	ICAO CAST description
A	Flight Crew deviate without ATC clearance	MAC, NAV	Classified as MAC if more than one aircraft involved
B	Incorrect estimate or route provided due to incorrect operations or interpretation of airborne equipment	MAC, NAV	Classified as MAC if more than one aircraft involved
C	Flight crew waypoint insertion error, due to correct entry of incorrect position or incorrect entry of correct position	MAC, NAV	Classified as MAC if more than one aircraft involved
D	ATC system loop error	MAC, NAV,ATM	Classified as MAC if more than one aircraft involved
E	Coordination error in ATC to ATC transfer of control responsibility as a result of human factors issues	MAC, ATM	Classified as MAC if more than one aircraft involved
F	Coordination errors in TAC to ATC transfer of control responsibility as a result of equipment outage or technical issue	MAC, ATM	Classified as MAC if more than one aircraft involved
G	Navigation errors due to airborne equipment failure	MAC, SCF-NP, LOC-I	Classified as MAC if more than one aircraft involved

H	Turbulence or other weather related caused leading to a deviation the horizontal dimension	TURB, WSTRW, ICE	
I	An aircraft was provided with reduced horizontal separation minima but did not meet the RNP/RSP/RCP specification	ATM, NAV	
J	Other		

Table 2: Mapping of LHD/LLE/LLD to ICAO CAST Taxonomy

2.8 Full list of LHD, LLE & LLD categories can be found in **Appendix B** for reference

3. ACTION BY THE MEETING

3.1 The Meeting is invited to:

a) note the information in this paper and the mapping of LHD/LLE/LLD categories in Table 2;

b) to provide inputs for RASMAG and/or RASMAG Monitoring Agency Working Group (MAWG) relating to data required for MAC analysis; and

c) discuss any relevant matters as appropriate.

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Appendix A - Extract of taxonomy from the ICAO CAST aviation occurrence categories

AIRPROX/TCAS ALERT/LOSS OF SEPARATION/NEAR MIDAIR COLLISIONS/MIDAIR COLLISIONS (MAC)

Air proximity issues, Traffic Collision Avoidance System (TCAS)/Airborne Collision Avoidance System (ACAS) alerts, loss of separation as well as near collisions or collisions between aircraft in flight.

Usage Notes: Includes:

- All collisions between aircraft while both aircraft are airborne.
- Separation-related occurrences caused by either air traffic control or cockpit crew.
- AIRPROX reports
- Genuine TCAS/ACAS alerts.

Does NOT include:

- False TCAS/ACAS alerts caused by equipment malfunctions, which are coded as SCF-NP.
- Loss of separation with at least one aircraft on the ground, which may be coded as ATM, GCOL, NAV, and/or RI if the occurrence meets the criteria and usage notes for those categories.

Crossover to/from other occurrence categories:

- Code both MAC and NAV if the event was caused by a navigation error and the event meets the usage notes of both categories.
- Code both MAC and ATM if the event was caused by an ATC/ATM error and the event meets the usage notes of both categories

ATM/CNS (ATM)

Occurrences involving Air Traffic Management (ATM) or Communication, Navigation, Surveillance (CNS) service issues.

Usage Notes:

- Includes Air Traffic Control (ATC) facility/personnel failure/degradation, CNS service failure/degradation, procedures, policies, and standards.
- Examples include NAVAID outage, NAVAID service error, controller error, supervisor error, ATC computer failure, radar failure, and navigation satellite failure.
- Occurrences do not necessarily involve an aircraft.

NOTE: ATM includes all of the facilities, equipment, personnel, and procedures involved in the provision of State-approved Air Traffic Services.

NAVIGATION ERRORS (NAV)

Occurrences involving the incorrect navigation of aircraft on the ground or in the air.

Usage Notes: Includes:

• Lateral navigation errors caused by navigating using the improper navaid or improper programming of aircraft navigation systems,

• Airspace incursions resulting from improper navigation, uncertainty of position, improper planning, or failure to follow procedures prior to entering airspace,

• Failure to accurately track navigation signals (lateral or vertical),

• Altitude/level busts (see below for exceptions),

• Deviating from ATC/ATM clearances or published procedures (SID/DP, STAR, approach procedures, charted visual procedures),

• Failure to follow clearances or restrictions while operating on the surface of an aerodrome, including

- Taxiing or towing an aircraft on an unassigned taxiway or runway (see crossover section below),
- Taxiing or otherwise operating an aircraft on a restricted portion of an aerodrome (cargo ramp, air carrier ramp, general aviation ramp, military ramp, wingspan- or weightrestricted taxiways or runways, etc.)
- Take-offs, aborted take-offs, or landings on a taxiway, unassigned runway, or closed runway (see below for exceptions),

• Approaches or landings to/on unassigned runways or to/at the wrong aerodrome.

• Taxiway excursions (except following a loss of control on the ground or intentionally steering an aircraft off a taxiway to avoid a collision).

Does NOT include:

• Intentional deviations resulting from a PIC exercising emergency authority.

• Deviations from assigned altitude or course to avoid other aircraft as a result of visual detection or complying with a TCAS RA, which are coded as MAC.

• Deviations from assigned altitude or electronic navigation path as a result of wind shear or turbulence, which are coded as WSTRW or TURB.

• Lateral or vertical deviations resulting from extreme manifestations of loss of aircraft control in flight, which is coded as LOC-I.

• Taxiway excursions due to a loss of control on the ground, which is coded as LOC-G. Revised 12/2017 Page 19

• Taxiway excursions to avoid a ground collision, which are coded as AMAN.

• Takeoffs, aborted takeoffs, landings, or approaches to engaged runways due to ATC/ATM error, which are coded as ATM (and MAC if it resulted in a loss of separation).

• Navigation errors at an aerodrome made by vehicles or pedestrians. Code RI if the navigation error results in the vehicle or pedestrian incorrectly entering a runway. Code RAMP if the error meets the usage notes for the RAMP category

LOSS OF CONTROL–INFLIGHT (LOC–I)

Loss of aircraft control while, or deviation from intended flightpath, in flight. Loss of control inflight is an extreme manifestation of a deviation from intended flightpath. The phrase "loss of control" may cover only some of the cases during which an unintended deviation occurred.

Usage Notes:

• Used only for airborne phases of flight in which aircraft control was lost.

• Loss of control can occur during either Instrument Meteorological Conditions (IMC) or Visual Meteorological Conditions (VMC).

• The loss of control during flight may occur as a result of a deliberate maneuver (e.g., stall/spin practice).

• Occurrences involving configuring the aircraft (e.g., flaps, slats, onboard systems, etc.) are included as well as rotorcraft retreating blade stall.

• Stalls are considered loss of control and are included here.

• Manned and unmanned rotorcraft (including multi-rotor) occurrences which involve power settling (vortex ring), or settling with power to ground contact are coded here and as Abnormal Runway Contact (ARC) if during normal landing or takeoff. Rotorcraft External Load operations involving loss of control related to the external load should be coded as LOC–I as well as External Load Related Occurrences (EXTL).

• Includes Rotorcraft "Loss of Tail Rotor Effectiveness."

• Includes loss of control during practice or emergency autorotation.

• Includes pilot-induced or assisted oscillations. • For unmanned aircraft events, includes hazardous outcomes involving deviation from intended flightpath associated with anticipated or unanticipated loss of datalink. However, if loss of datalink is the direct result of a system/component failure or malfunction, code the occurrence as System/Component Failure or Malfunction (Non-Powerplant) (SCF–NP) only.

• For icing-related events, which are also loss of control, code both LOC–I and Icing (ICE)).

• If the loss of control is a direct result of a system/component failure or malfunction (SCF), code the occurrence as an System/Component Failure or Malfunction (Non-Powerplant) (SCF–NP), or System/Component Failure or Malfunction (Powerplant) (SCF–PP) only. However, loss of control may follow less severe system/component failures, and in this case, code both categories.

• Cockpit crew vision-related events and flight in degraded visual environments (for example, obscuration, black hole approach events, brownouts, or whiteout events), in which the aircraft is flown under control into terrain, water, or obstacles, are coded under Controlled Flight Into or Toward Terrain (CFIT), not LOC–I

TURBULENCE ENCOUNTER (TURB)

In-flight turbulence encounter.

Usage Notes:

• Includes encounters with turbulence in clear air, mountain wave, mechanical, and/or cloud-associated turbulence.

• Wake vortex encounters are also included here.

• Flights into wind shear or thunderstorm-related turbulence are coded as Wind Shear or Thunderstorm (WSTRW).

• Includes turbulence encountered by aircraft when operating around or at buildings, structures, and objects.

SYSTEM/COMPONENT FAILURE OR MALFUNCTION (NON-POWERPLANT) (SCF–NP)

Failure or malfunction of an aircraft system or component other than the powerplant.

Usage Notes:

• If the failure renders the aircraft uncontrollable it is coded as SCF–NP only, not as loss of control (Loss of Control–Inflight (LOC–I) or Loss of Control–Ground (LOC–G)). However, if the failure does not render the aircraft uncontrollable, but leads to a loss of control, code the event under both SCF–NP and LOC–I or LOC–G, as appropriate.

• Rotorcraft main rotor and tail rotor system, drive system and flight control failures or malfunctions are also coded here.

• Includes errors or failures in software and database systems.

• Includes non-powerplant parts or pieces separating from an aircraft.

• For unmanned aircraft, includes failure or malfunction of ground-based, transmission, or aircraft-based communication systems or components or datalink systems or components.

• Includes failures/malfunctions of ground-based launch or recovery systems equipment.

• Includes all failures/malfunctions, including those related to or caused by maintenance issues

ICING (ICE)

Accumulation of snow, ice, freezing rain, or frost on aircraft surfaces that adversely affects aircraft control or performance.

Usage Notes:

• Includes accumulations that occur in flight or on the ground (i.e., deicing-related).

• Carburetor and induction icing events are coded in the Fuel Related (FUEL) category.

• Windscreen icing which restricts visibility is also covered here.

• Includes ice accumulation on sensors, antennae, and other external surfaces.

• Includes ice accumulation on external surfaces including those directly in front of the engine intakes.

WIND SHEAR OR THUNDERSTORM (WSTRW)

Flight into wind shear or thunderstorm.

Usage Notes:

• Includes flight into wind shear and/or thunderstorm-related weather.

• Includes in-flight events related to hail.

• Includes events related to lightning strikes.

• Includes events related to heavy rain (not just in a thunderstorm).

• Icing and turbulence encounters are coded separately (see Icing (ICE) and Turbulence Encounter (TURB)).

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Appendix B – Category List of LHD, LLE & LLD

LHD CATEGORIES

The following category codes are mainly for the use of RMAs. However, reporters may use this categorization as a referenc common causes of LHDs.

Code	RVSM Operations LHD Categorization
Operational Errors	
A	Flight crew failing to climb/descend the aircraft as cleared Example: Aircraft A was at FL300 and assigned FL360. A CLAM alert was seen as the aircraft passed FL364. The Mode C level reached FL365 before descending back to FL360.
B	Flight crew climbing/descending without ATC Clearance
C	Incorrect flight level provided due to incorrect operation or interpretation of airborne equipment (e.g. incorrect operation of fully functional FMS, incorrect transcription of ATC clearance or re-clearance in FMS, flight plan followed rather than ATC clearance, original clearance followed instead of re-clearance etc.) Example: The aircraft was maintaining a flight level below the assigned altitude. The altimeters had not been reset at transition. The FL assigned was 350. The aircraft was maintaining FL346 for in excess of 4 minutes.
D	ATC system loop error; (e.g. ATC issues incorrect flight level clearance or flight crew misunderstands flight level clearance message.) Example: All communications between ATC and aircraft are by HF third party voice relay. Aircraft 1 was maintaining FL360 and requested FL380. A clearance to FL370 was issued, with an expectation for higher levels at a later point. A clearance was then issued to Aircraft 2 to climb to FL390, this was correctly read back by the HF operator, but was issued to Aircraft 1. The error was detected when Aircraft 1 reported maintaining FL390.
E	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of human factors issues (e.g. late or non-existent coordination of flight level) Example 1: Sector A coordinated Aircraft 1 to Sector B at FL380. The aircraft was actually at FL400. Example 2: The Sector A controller received coordination on Aircraft 1 for Waypoint X at FL370 from Sector B. At 0504 Aircraft 1 was at Waypoint X at FL350 requesting FL370.
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues (e.g. late or non-existent coordination of flight level) Example: Controller in FIR A attempted to send AIDC message to coordinate transfer of aircraft at FL320. Messaging was unsuccessful to contact adjacent FIR by telephone fail. Aircraft contacted adjacent FIR without coordination being completed.
Aircraft Contingency Events	
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level (e.g. pressurization failure, engine failure) Example: Aircraft 1 descended from F400 to F300 with a pressurisation issue.
H	Airborne equipment failure leading to unintentional or undetected change of flight level Example: Aircraft 1 cruising at FL380. ATC receives alert indicating aircraft climbing through FL383. Flight crew advises attempting to regain cleared level with autopilot and navigation system failure.

Appendix B

Deviation due to Meteorological Condition	
I	Turbulence or other weather related causes leading to unintentional or undetected change of flight level Example: During the cruise at F400, the aircraft encountered severe turbulence, resulting the aircraft descending 1,000 ft without a clearance.
Deviation due to TCAS RA	
J	TCAS resolution advisory, flight crew correctly climb or descend following the resolution advisory Example: Aircraft 1 was cruising at FL350. Flight crew received "Traffic Alert" from TCAS and almost immediately after an "RA Climb" instruction. Flight crew responded and climbed Aircraft 1 to approx FL353 to comply with TCAS instruction. TCAS display indicated that opposite direction Aircraft 2 descended to approx FL345 and passed below Aircraft 1.
K	TCAS resolution advisory, flight crew incorrectly climb or descend following the resolution advisory
Others	
L	An aircraft being provided with RVSM separation is not RVSM approved (e.g. flight plan indicating RVSM approval but aircraft not approved, ATC misinterpretation of flight plan) Example 1: Original flight plan details submitted by FIR A for outbound leg showed Aircraft 1 as negative RVSM. Subsequent flight plan submitted by FIR B showed Aircraft 1 as RVSM approved. FIR A controller checked with aircraft shortly after entering FIR A and pilot confirmed negative RVSM. Example 2: Aircraft 2 cruising FL310 was handed off to the Sector X controller who noticed the label of Aircraft 2 indicated RVSM approval. The Sector X controller had controlled the aircraft the day before. It was then a non-RVSM aircraft. The controller queried the status of Aircraft 2 with the pilot who advised the aircraft was negative RVSM.
M	Other

Categories of LLD & LLE

Attributions	Category Code	Description
Aircrew/ Pilot	A	Flight crew deviate without ATC Clearance
	B	Incorrect estimate or route provided due to incorrect operation or interpretation of airborne equipment
	C	Flight crew waypoint insertion error, due to correct entry of incorrect position or incorrect entry of correct position
ATC	D	ATC system loop error
	E	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of human factors issues
	F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues

Attributions	Category Code	Description
Aircraft/ Avionics/ Contingencies	G	Navigation errors due to airborne equipment failure
Weather/ Turbulence	H	Turbulence or other weather related causes leading to a deviation in the horizontal dimension
Other	I	An aircraft was provided with reduced horizontal separation minima but did not meet the RNP/RSP/RCP specification;
	J	Other

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