International Civil Aviation Organization

The 17th Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/17)

Bangkok, Thailand, 27 – 31 August 2012

Agenda Item 3: Reports from Asia/Pacific RMAs and EMAs

FUKUOKA FIR HORIZONTAL SEPARATION SAFETY ASSESSMENT

(Presented by Japan)

SUMMARY

This paper presents the recent work of Japan Airspace Safety Monitoring Agency (JASMA) as an En-route monitoring agency (EMA) within the Fukuoka Flight Information Region (FIR).

This paper relates to –

Strategic Objectives:

*A: **Safety** – Enhance global civil aviation safety*

1. INTRODUCTION

1.1 The Japan Airspace Safety Monitoring Agency (JASMA) has started En-route Monitoring Agency (EMA) works officially with the endorsement of APANPIRG/22 in September, 2011. JASMA continues the safety monitoring as an EMA focused on PBN-based lateral separation and PBN/Data Link-based longitudinal/lateral separation in Pacific Ocean airspace of Fukuoka FIR.

2. DISCUSSION

Monitoring of horizontal plane navigation performance

2.1 An EMA must be prepared to collect the information necessary to monitor horizontal-plane navigational performance as part of the risk assessment.

2.2 RNP10-based 50/50 separations and trial operation of RNP4-based 30/30 separations have been already introduced in the Pacific Ocean airspace of Fukuoka FIR, and JASMA monitors their safe operations. Large Lateral Deviation (LLD) and Large Longitudinal Error (LLE) occurred are reported to JASMA, which are also reported to FAA's Technical Center (PARMO) in accordance with the bilateral Letter of Agreement between Japan and USA. JASMA received six (6) LLD reports during the period from 1 May 2011 to 30 April 2012.

2.3 Based on the information provided from ATC facilities the LLD and LLE reports are categorized. These categories are defined in the ICAO Asia Pacific Region's EMA Handbook. **Table 1** and **Table 2** shown the summary of six (6) LLD reports received by JASMA from 1 May 2011 to 30 April 2012. No LLE reports were received during the period.

Deviation Code	Cause of Deviation	No. of Occurrences
Operational Errors		
A	Flight crew deviate without ATC Clearance;	1
D	ATC system loop error (e.g. ATC issues incorrect clearance, Flight crew misunderstands clearance message etc);	4
Deviation due to Meteorological Conditions		
G	Turbulence or other weather related causes (other than approved);	1
Total		6

Table 1: Summary of LLD occurrence in the Fukuoka FIR

Event date	Source	Location of deviation	Deviation(NM)	Duration
29-May-11	ATMC	30N160E-33N150E	unknown	13 minutes
24-Aug-11	ATMC	ADGOR- AGEDI (R591)	10NM	unknown
31-Oct-11	ATMC	40N155E-43N159E	10NM (right), 23NM (left)	unknown
8-Dec-11	ATMC	SEALS- 36N150E-37N170E	120NM long (latitude 2 degrees)	unknown
14-Dec-11	ATMC	SABGU-PAKDO (G339)	150NM long (KEITH-PAKDO)	unknown
21-Mar-12	ATMC	40N160E-41N165E	unknown	unknown

Table 2: LLD occurred in the oceanic airspace of Fukuoka FIR (May 2011-April 2012)

2.4 Out of six (6) LLD reports categorized four (4) as D were caused by the mismatches in the cognition of valid flight plan routes between pilots and air traffic controllers. In these cases wrong registration of flight plan into the flight plan data system was made at the departing airport, and flight plan CHG (change route) and/or CX (cancel) messages were not adequately processed. One (1) was categorized as G (Turbulence or other weather related causes) and the other was the controller could not receive the reason of deviation.

Summary of the original report on 29 May 2011 - This westbound aircraft proceeding to 33N150E instead of flight planned 31N150E at 160E position report. The controller confirmed to the pilot in command the latitude of 150E and re-cleared the route of flight in accordance with the pilot's intention.

Summary of the original report on 24 August 2011 - This north-eastbound aircraft was deviated 10NM to the left of course. The controller tried to confirm the reason to the pilot in command by CPDLC but could not receive the answer.

Summary of the original report on 31 October 2011- This eastbound aircraft deviated without clearance. After the controller confirmed the answer was "We did deviate left of course for weather but are currently back on course."

Summary of the original report on 8 December 2011 - This eastbound aircraft reported the next waypoint would be 35N170E instead of flight planned 37N170E at 160E. ABI (Advance Boundary Information) message had already sent to the next ATC facility Oakland ARTCC via CPDLC (Controller Pilot Data Link communication), who asked ATMC controller the latitude of 170E. The controller confirmed to the pilot in command the latitude of 170E. The pilot answered the latitude of the next waypoint will be 35N.

Later ATMC was reported that the flight services at the departing airport made wrong input to the flight plan data system.

Summary of the original report on 14 December 2011 - The original route of flight was SABGU-A339-KEITH but the aircraft flew SABGU-G339-PAKDO. Later ATMC was reported that the dispatcher could not send the change message appropriately because the address was wrong.

Summary of the original report on 21 March 2012 - The original route of flight was 40N160E-43N170E but the aircraft flew 40N160E-41N165E. The controller re-cleared the route of flight in accordance with the pilot's intention.

Data link performance Monitoring

2.5 JASMA has reviewed the data link performance analyzed by Japan Central Reporting Agency (CRA), which is important as these performances are the basis for the reduced separation minima. Detailed information was provided to the FIT-Asia as IP04. The average success rate during the observation period for Controller Pilot Data-link Communication (CPDLC) was 99.13%.

Downlink: 95 %(99%) of whole messages were completed within 1min. (3min.)
Uplink: 95 %(99%) of whole messages were completed within 2min. (6min.)

2.6 Regarding the result of Automatic Dependent Surveillance (ADS) report performance, 95 % (99%) of whole messages were completed within 1min. (3min.)

Risk assessment procedure

2.7 At RASMAG 15, Japan Airspace Safety Monitoring Agency (then Japan Civil Aviation Bureau RMA) had presented the calculation results, based on time-based separation collision risk model (CRM), of longitudinal collision risk values on oceanic routes in Fukuoka FIR.

2.8 We also announced to report the risk calculation result based on distance based CRM as a next step. Although we presented theoretical outline of the distance based CRM, but could not produce actual calculated values of collision risk. This paper presents the review of the distance based CRM and a results of the risk calculation of the distance based collision estimation of the airway R220 by JASMA.

Review of distance-based CRM

2.9 Risk calculation methodology used in this assessment was mainly developed by SASP and other ICAO safety assessment members. The actual calculation devices are developed by Electronic Navigation Research Institute (ENRI). For the detailed explanation of the methodology, please refer to the papers like "Safety Assessment prior to 30 NM Longitudinal Separation Minimum under ADS-C environment SASP-WG/WHL/13-IP/08 and others.

2.10 Here we assume that except the cases caused by pilot or ATC mismanagement aircraft collision will be caused by two errors. Those are 1) navigational position errors and 2) position estimation errors. We focus here a pair of (two) aircraft flying on the same route at the same altitude. ADS-C equipped aircraft periodically (usually every 1600 seconds) send their current GPS and future FMS calculated positions via SATCOM/INMARSAT/MTSAT data link communication. These positions include some navigational errors. The aircraft also send estimated position for the next reporting time. Based on these two data and wind factors the Oceanic Data Processing System (ODP) calculates the aircraft speed and extrapolate the displayed position to which ATC applies distance separation.

2.11 The algorithm to calculate the extrapolated position is not open, but presumably these extrapolated positions will contains increasing errors as time elapse. Consequently, the position error on the ODP display tends to grow till ATC receives the next (new) position report. **Figure 1** shows the flow of the aircraft position data.

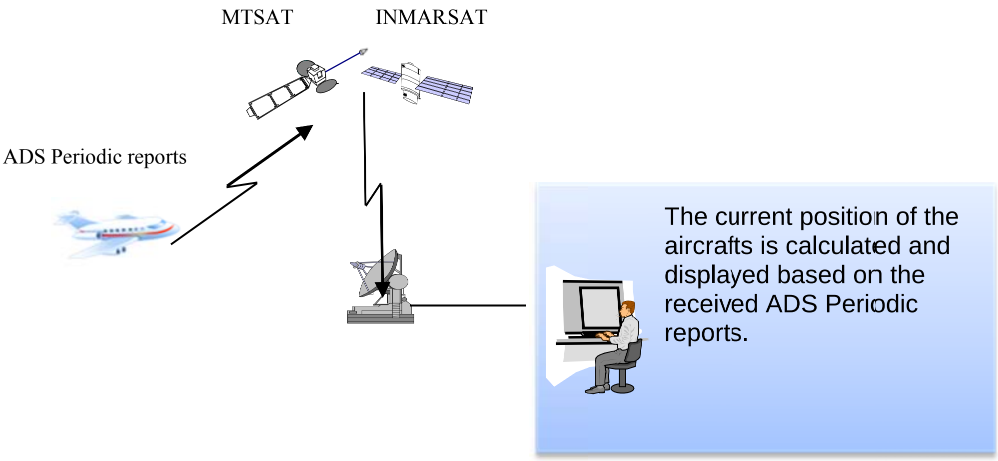

Figure 1: Flow of the aircraft position data

2.12 In the following formula (1) "T" is the ADS-C position reporting time interval. The value ΔT is the gap between the reporting timing of two aircraft and "t" is the elapsed time from the reception of the last message transmitted by the first aircraft. The x_1 and x_2 denote the reporting positions which contain some positional errors of these two aircraft pair, and v_1 and v_2 are the estimated longitudinal speeds of two aircraft. Then the longitudinal position error is given by formula (1). Figure 2 illustrates the relation of these factors.

$$d = \begin{cases} x_1 - x_2 + v_1 t - v_2 (T - \Delta T + t) & t < \Delta T \\ x_1 - x_2 + v_1 t - v_2 (T - \Delta T) & t \geq \Delta T \end{cases} \quad (1)$$

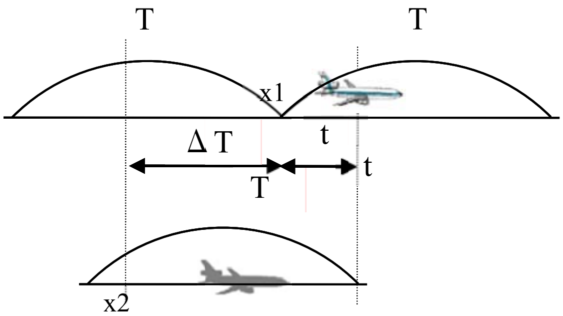

Figure 2: Relations among related factors.

2.13 Let $f_x(d;v_1,v_2,t,\Delta T,T)$ be the probability density function of "d" where variables v_1, v_2, t, ΔT and T are constants. Then the longitudinal overlapping probability of a typical aircraft pair is given by the following formula (2).

$$P_x(x;\tau) = \frac{1}{T(T+\tau)} \int_0^T \int_0^{T+\tau} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{x-\lambda x}^{x+\lambda x} f_d(x;v_1,v_2,t,\Delta T) f_v(v_1) f_v(v_2) dx dv_1 dv_2 dt d(\Delta T) \tag{2}$$

$$P_x(x;\tau) = \frac{1}{T(T+\tau)} \int_0^T \int_0^{T+\tau} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{x-\lambda_x}^{x+\lambda_x} f_d(u;v_1,v_2,T,\Delta T) f_v(V_1) f_v(V_2) du dv_1 dv_2 dt d(\Delta T)$$

The individual parameters for the equation (2) and their definitions are given in **Table 3**.

Parameter	Description	Parameter Value	Source for Value
$P_x(x;\tau)$	Longitudinal overlap probability. Mean probability that a typical aircraft pair which is nominally x NM separated on the same route at the same flight level overlaps in the longitudinal dimension.	----	----
$f_v(V)$	Probability density function of longitudinal speed prediction errors. (Prediction is done by ODP using the ADS-C message down linked from the aircraft) It is determined by the accuracy of position prediction by the aircraft, the performance of the ground ATC system interpolation/extrapolation function and so on.	----	----
$f_x(d;v_1,v_2,t,\Delta T,T)$	Probability density function of longitudinal position errors d at the given v_1 v_2, t and ΔT. It is calculated by means of equation (1).	----	----
T	Reporting interval of ADS position report.	1600sec	Standard Oceanic ADS-C Reporting Interval
τ	Time required for the resolution of a potential collision.	----	See Table****
λ_x	Average aircraft length	0.0279NM	Estimated from TSD Dec. 2011

Table 3: Parameters in equation (2)

2.14 Using the longitudinal overlapping probability, the collision risk is estimated by the following formula (3).

$$N_{ax}(x;\tau) = 2 \cdot P_y(0) \cdot P_z(0) \cdot P_x(x;\tau) \cdot \left(\frac{V_{rx}}{2\lambda_x} + \frac{V_{ry}}{2\lambda_y} + \frac{V_{rz}}{2\lambda_z} \right) \tag{3}$$

The individual parameters for the equation (3) and their definitions are given in **Table 4**.

Parameter	Description	**Parameter Value**	**Source for Value**
$N_{ax}(x;\tau)$	Collision risk of a typical aircraft pair on the same route at the same flight level whose nominal separation is x (NM). Remember that τ is the time required for the resolution of a potential collision.	----	----
$P_y(0)$	Lateral overlap probability. Probability that an aircraft pair on the same route overlaps in the lateral dimension.	0.0719	Estimated from processing Hachinohe SSR DATA(2002) and FDPS data (Dec. 2011)
$P_z(0)$	Vertical overlap probability. Probability that an aircraft pair at the same flight level overlaps in the vertical dimension.	0.54	RVSM/TF-9-IP/2
$V_{rx}(x)$	Average longitudinal relative velocity of aircraft pairs which are about losing their longitudinal separation in spite of the nominal x NM separation.	----	Assumption $v_{rx} = \frac{x}{T+\tau}$
V_{ry}	Average lateral relative velocity of aircraft pairs on the same route.	1knot	EMA HAND BOOK
V_{rz}	Average vertical relative velocity of aircraft pairs at the same flight level.	1.5knots	ICAO SASP
λ_y	Average aircraft length	0.0254NM	Estimated from TSD Dec. 2011
λ_z	Average aircraft height	0.0081NM	Estimated from TSD Dec. 2011

Table 4: Parameters in equation

(3) $N_{ax}(x;\tau) = 2 \cdot P_y(0) \cdot P_z(0) \cdot P_x(x;\tau) \cdot \left(\frac{\overline{|\Delta V|}}{2\lambda_x} + \frac{\overline{|\dot{y}|}}{2\lambda_y} + \frac{\overline{|\dot{z}|}}{2\lambda_z} \right)$

2.15 In the previous equation, the distribution of nominal separation is fixed. When relative frequency for the aircraft pair that are flying on the same route and same altitude with the nominal (the displayed separation of the aircraft on the ODP consoles) separation of x(s) are given, collision estimation with resolution time is estimated by equation (4).

$$N_{ax}(\tau) = \sum_{x=0}^{\infty} N_{ax}(x;\tau) E_x(x) \qquad (4)$$

2.16 The individual parameters for the equation (4) and their definitions are given in **Table 5**.

Parameter	Description	**Parameter Value**	**Source for Value**
$N_{ax}(\tau)$	Collision risk value. Where τ is the time required for the resolution of a potential collision.	----	----
$E_x(x)$	The relative frequency for the aircraft pair that are flying on the same route and same altitude with the nominal separation of x.	----	Estimated from processing Flight Plan data and ADS-C position reports

Table 5: Parameters in Equation (4)

2.17 Finally CPDLC uplink time is taken into consideration. The average collision risk with respect to this parameter is given by

$$N_{ax} = \sum_{\tau=0}^{\infty} N_{ax}(\tau) E_{\tau}(\tau) \qquad (5)$$

2.18 The individual parameters for the equation (5) and their definitions are given in **Table 6**.

Parameter	Description	**Parameter Value**	**Source for Value**
N_{ax}	Collision risk in the considered ADS-Environment.	----	----
$E_{\tau}(\tau)$	The relative frequency of time required to resolve a potential collision.	----	Estimated from processing Flight Plan data and ADS-C position reports.

Table 6: Parameters in Equation (5)

Collision risk estimation procedure

2.19 The airway we considered was airway R220 in NOPAC routes. NOPAC (North Pacific routes) is consists of 5 routes, namely R220, R580, A590, R591, G344. The NOPAC routes are the busiest route in the oceanic airspace of Fukuoka FIR.

2.20 The applicable longitudinal separation can vary depending on the airways and aircraft RNP. Aircraft-pairs entering NOPAC routes, the applicable longitudinal separation at the FIR boundary is 50NM for RNP10or4/ADS-C/CPDLC-based aircraft or 10 minutes with MNT. The trial 30NM separation for aircraft pair with which RNP4 are available is now in progress. However that number is still limited, here in this report we handle 50NM ADS-C based separation only. R220, the airway under consideration is shown in **Figure 3**.

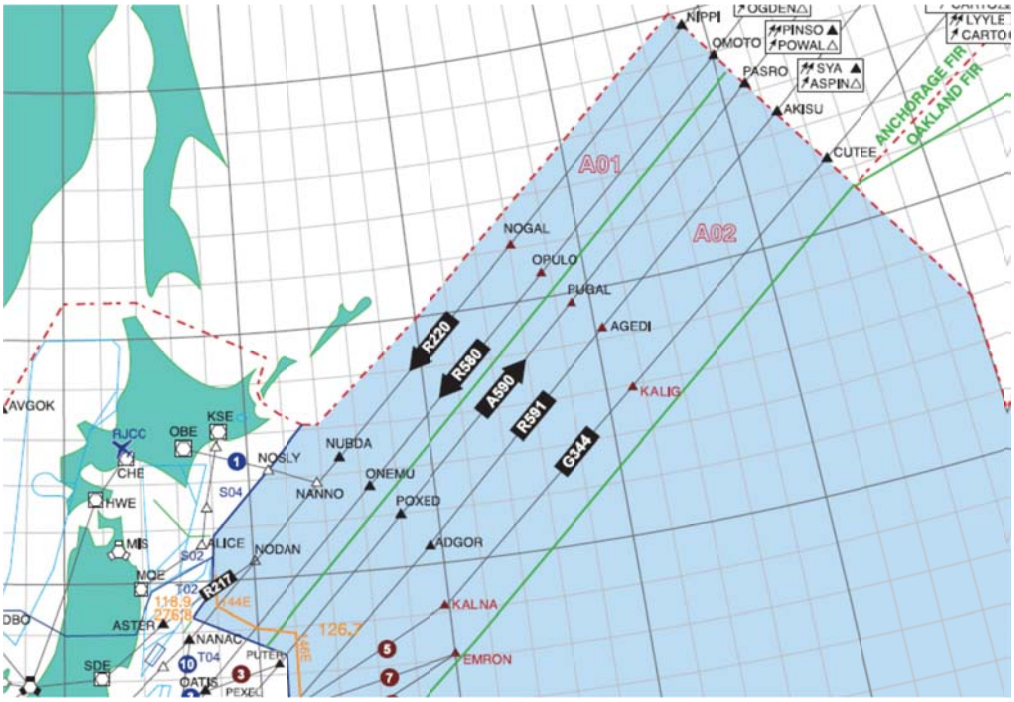

Figure 3: Airway R220 in NOPAC.

2.21 We used the set of programs provided by the ENRI for risk calculation named DATMA (Data Analyzing Tools for Monitoring Agency). DATMA is a set of programs to analyze Flight Plan data, RADAR data, and ADS-C data. DATMA itself does not provide the program to get the final result of the risk value but it provide various supporting functions.

2.22 This Risk estimation was done under following assumptions.

a) Aircraft under consideration is the Flights on R220 with 50NM longitudinal separation. (The relative frequency Ex(x) is estimated by analyzing Flight on R220)

b) All Aircraft flying with navigational accuracy of RNP4. (Safe side assumption, GPS non GPS mixed environment is not considered.)

c) The position errors of the aircraft are estimated by comparison of ADS-C position estimate and actual reported position. These position errors are converted to the speed errors.

d) Uplink times are collected by analyzing ODP's DLCS data.

e) Time required for collision resolution is 150 seconds. (See Ref. Anderson, D., A Collision Risk Model Based on Reliability Theory that Allows for Unequal RNP Navigation Accuracy, ICAO SASP-WG/WHL/7-WP/20, Montreal, May 2005)

2.23 For the time to collision avoidance operation by the controller, we used the value 150 seconds provided by AAMA. The total time for collision avoidance instructions will be estimated by value X shown in **Table 7**.

DATE	2011 Dec		
N of msg.	27,707		
X<=10(sec)	18674	67.40%	67.40%
10(sec)<X<= 20(sec)	6813	24.59%	91.99%
20(sec)<X<= 30(sec)	983	3.55%	95.54%
30(sec)<X<= 60(sec)	831	3.00%	98.53%
60(sec)<X<= 90(sec)	215	0.78%	99.31%
90(sec)<X<=120(sec)	143	0.52%	99.83%
120(sec)<X<=180(sec)	24	0.09%	99.91%
180(sec)<X	24	0.09%	100.00%

Table 7: CPDLC Uplink time

2.24 The longitudinal collision risk was estimated in order to determine whether the TLS is met on airway R220. The technical risk is estimated to be 1.795×10^{-13}. This estimate meets the TLS value of 2.5×10^{-9}. The operational risk is presently not available due to the difficulties in collecting appropriate data for risk estimation.

Fukuoka RVSM Airspace R220 ADS-C aircraft -estimated annual flying hours=1722:hours(note: estimated hours based on December 2011 traffic sample data)			
Source of Risk	**Estimated Risk**	**TLS**	**Remarks**
Technical Risk	1.795×10^{-13}	$2.5*10^{-9}$	Below Technical TLS
Operational Risk	N/A	N/A	
Total Risk	N/A	N/A	

Table 8: Risk Estimates

<u>Difficulties</u>

2.25 Even if the CRM was well devised and provided by the mathematician when it came to actual calculation we often had practical difficulties. This was the part of reason why JASMA's plan to present a safety assessment for the distance-based reduced longitudinal separation was delayed.

2.26 The flight plan data recorded in the FDPS does not always reflects actual flight tracks. Aircraft flying out of domestic area into the oceanic airways often omitting entry fix and flies directly to the second or third fix in the oceanic route. This rather common practice is beneficial to both controllers and pilots. In some of these short cut routing cases, the input into the FDPS is often omitted. This causes discrepancy between actual times and recorded times.

2.27 **Figure 4** shows the example of short cut route. The solid line shows the actual short cut track, while the dotted line shows the original track.

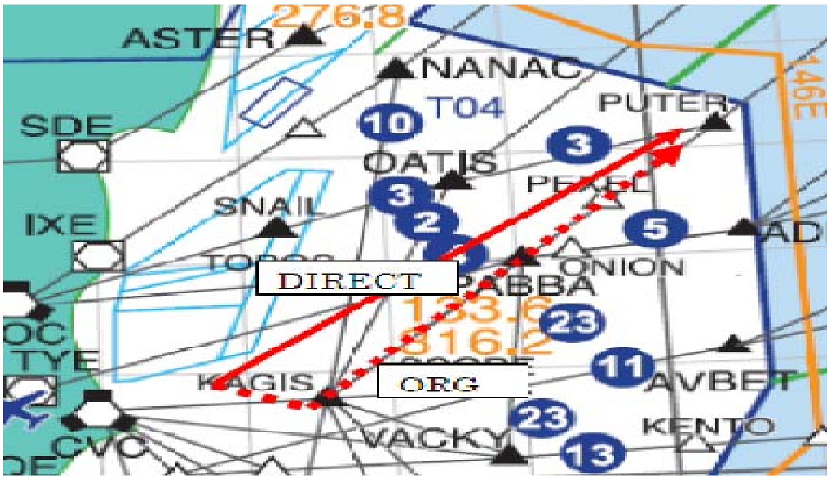

Figure 4: Short Cut.

2.28 Some of the vital information are not recorded. For instance the applied separation by the controllers are not recorded. So for the pair of aircraft flying 50NM separation, we cannot determine whether the aircraft is flying 30NM separation or 50NM separation. This is the same with aircraft navigation. The aircraft equipped with GPS (RNAV4, RNAV0.3) does not always mean it utilizing her full navigational capacity.

2.29 FDPS journaling system is subject to frequent format changes. We have already experienced three such changes. And another FP format change is scheduled on 15th of Dec. 2012. This often necessitates changes in decoding programs.

2.30 In some cases the fidelity of the data itself became questionable. It needs quite a time to identify causes of these problems. But such an extraordinary data often has a vital importance when calculating the risk. So we have to come through these data and this is really time-consuming.

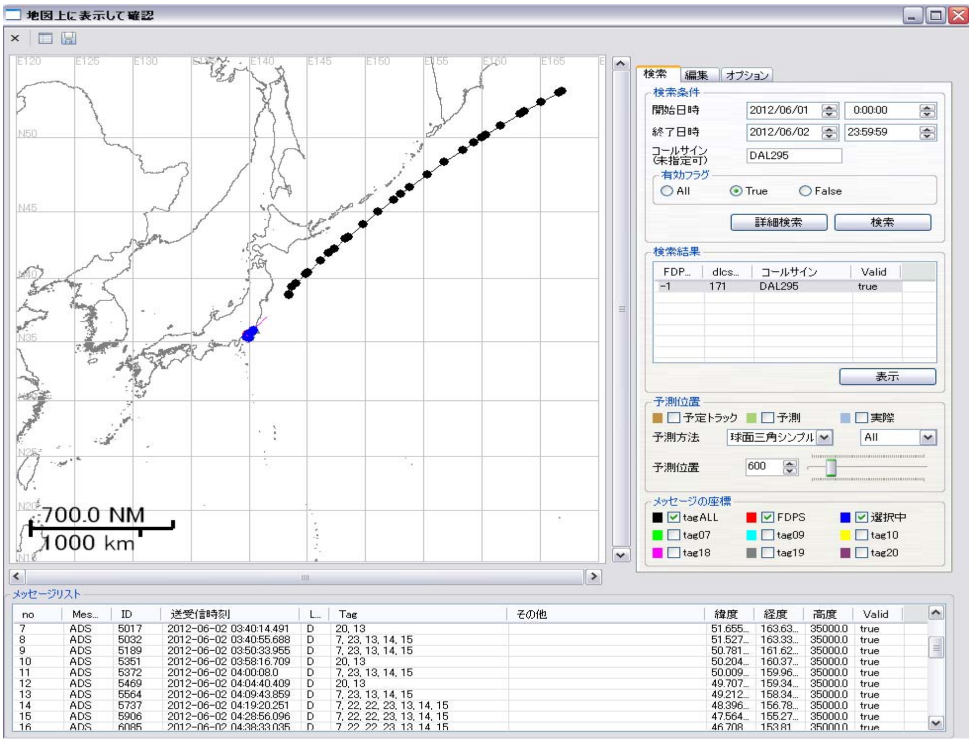

Figure 5: An Example of GUI.

2.31 To alleviate these difficulties ENRI developed a supporting tool to identify the data that lacks some coherence. Using the FP data, Radar data, ADS-C messages, DATMA can verify the consistency among data and it can automatically set the validity flag for each data. But there still exists quite a number of extra ordinary data that requires human intervention for validation. For this objective DATMA also provides GUI for further validity check if necessary. The user confirms the actual track and related information on the CRT. The false/true flag can be changed depending on check results. The data checked out false will be remain kept in the DB but will not be used for risk estimation.

Iridium communication within Fukuoka FIR

2.32 In Fukuoka FIR oceanic airspace, FOI (FANS/1 Over Iridium) is used for only communication, it is not used for providing ADS separation. One of the main reasons is that JCAB (Japan Civil Aviation Bureau) is not yet determined to apply GOLD (Global Operational Data Link Document) as guidance material. According to the result of a provisional verification of FOI data, the level of performance was below the GOLD. JCAB is preparing to publish how to deal with FOI aircraft in the AIR (Air Information Publication).

2.33 JCAB is preparing to apply GOLD as guidance material. It is not yet determined but JCAB will apply GOLD after conduct performance assessment as soon as applicable. JCAB will continue FOI performance monitoring until it satisfy the equivalent performance with MTSAT and IMMARSAT to applying ADS separation using FOI.

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 matters as appropriate.

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