



ADS-B Trials : Feedback



ICAO Surveillance Seminar for the NAM/CAR/SAM
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When considering operational ADS-B implementation, a number of items need to be defined:

- the scope of ADS-B surveillance: for situational awareness or for separation,
- the type of airspace: en-route, TMA, upper, lower, with or without existing radar coverage, and associated coverage
- the time frame considered,
- Preparation and publication of necessary regulatory material
- Organisation of controller training, users educations,

The relevant evolution of ground infrastructure must be considered:

- Network of ADS-B ground stations, and supported services, including communications
- Upgrade of the automation systems in order:
 - to receive and process ADS-B data,
 - to create tracks derived from ADS-B data (priority scheme or data fusion)
 - to display the resulting tracks with appropriate symbols
 - possibly to display associated DAPs
 - possibly to compute and display RAIM outages



To support the analysis of ADS-B implementation in a state or a region, ADS-B trials need to be set-up to allow the direct observation and analysis of a number of parameters:

- the status of the aircraft fleet in this state or region wrt ADS-B equipage,
- the local characteristics of the GPS signal, which directly generate the aircraft position reported by ADS-B
- The impact of local environment (physical, radio, ...) on the expected performance of the ADS-B surveillance

The results of such trials definitely contribute to a decision for implementation.

It will support dialogue with airlines for buy-in and plans to equip (or understand reasons for reluctance),

It will provide inputs for the preparation of safety case, etc, ...



The set-up for ADS-B trial can be simple, as it generally consists of:

- a single channel ADS-B ground station (redundancy is not strictly necessary),
- associated with a GPS equipped / RAIM reporting site monitor,
- a local or remote and control system (depending on where the station is installed),
- data recording capability and
- replay / data analysis tools,
- and the availability of experts resource to carry out the analysis



The trial will allow to provide more results when

- A radar covers the same area as the ADS-B ground station
 - Compare ADS-B and radar reports, tracks
- Several radar covers at least a part of the area covered by the ADS-B Ground Station and a multi-radar tracking system is applied
 - Multi-radar tracks can provide an accurate reference track

Methodology of Data Analysis

- Which data to be recorded for analysis depends on the intended operations i.e. whether it is en-route overflights, en-route domestic, approach in large TMA, and/ or approach to small airports.
- Depending on the operations required, the performance assessment might differ.

An example of trial objectives can be:

- Collection and analysis of the quantity and registration numbers of ADS-B equipped aircraft received by ADS-B ground station, on a daily basis over a period of 6 months;
- Conclusion on the validity of the reports received to allow surveillance and/or separation of aircraft based on ADS-B
- Comparison of ADS-B targets to radar targets functionality and recommendations

Which data to analyse? (2)



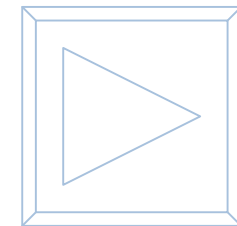
Analysis to be carried out on data collected may include the following:

- For aircraft sorted by airline / type / ...the analysis of the content of the squitter (i.e. what are the fields provided, level of NUC, ...)

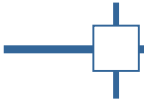
- For the whole population of aircraft observed, establish a data base identifying the aircraft with “good” ADS-B equipment and those with “bad” ADS-B equipment; the “bad” characteristic may come from an already identified issue or be a new one

- For selected tracks with good NUC values assess:
 - position accuracy, including investigation on along tracks error (on-board latency)
 - update rate figures
 - the ground station range and compare with theoretical model

- For selected tracks evaluate % of equipped aircraft ?



THALES



Feedback on trials



Thales contributed to a number of trials, including

- Germany, Langen with DFS
 - Spain, Madrid with AENA
 - Island, Reykjavik
 - Senegal, Dakar, ASECNA
 - India, Delhi, AAI
 - South Korea, Seoul (Incheon)
 - CRISTAL MED : France (Marseille, Corsica), Greece & Cyprus
- Cristal Toulouse (France), as part of Eurocontrol Cascade
 - Hong Kong
 - Indonesia



Eurocontrol Cascade – Cristal Toulouse - 2006

- Check conformity between ADS-B data sent by aircraft (flight test recorded data at sensors level) and data received by ground station (raw data).
- Verify that rate of transmission is compliant with ED-102/DO-260/DO-260A MOPS (airborne, ground)
- Evaluate the ADS-B ground station coverage (airborne, ground).
- Evaluate transmitted Flight ID and evaluate the percentage of aircraft sending a correct one (compliant with ICAO model).
- List airliners with ADS-B capability
- Evaluate integrity indicator (percentage per integrity indicator value)
- Make a comparison table of transponders ADS-B performance (transmission rate, data), according to the transponder type (3 types of equipment)

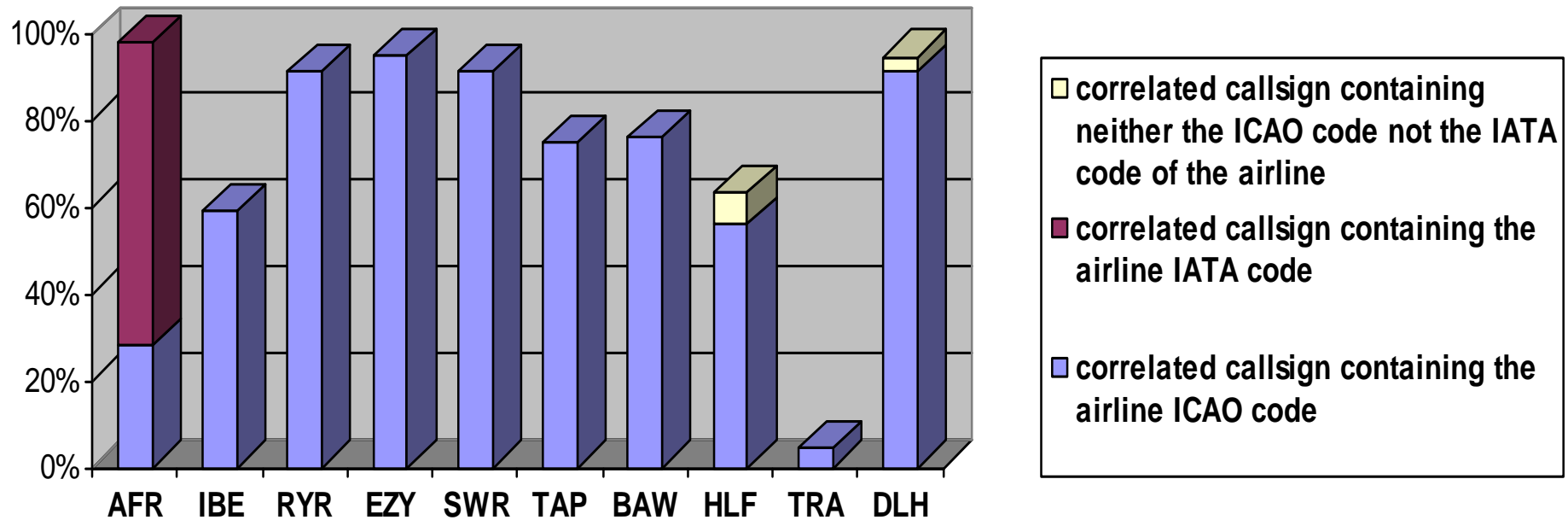
One Thales AS680 ADS-B Ground Station installed on the airport surface

- Not optimum location, antenna set on the ground and therefore visibility is limited
- Raw data collection on Local Maintenance & Control System
- ADS-B Asterix Cat21 reports sent through telecom line to French DGAC facility, a few km away, and recorded there
- 3 MSSR (Thales) + 1 MSSR Mode S (Thales)

Airbus test aircraft + Opportunity flights

Duration of data recording : 9 months (May 05-January 06)

Amount of collected data : >40Go (including ADS-B +radar data)



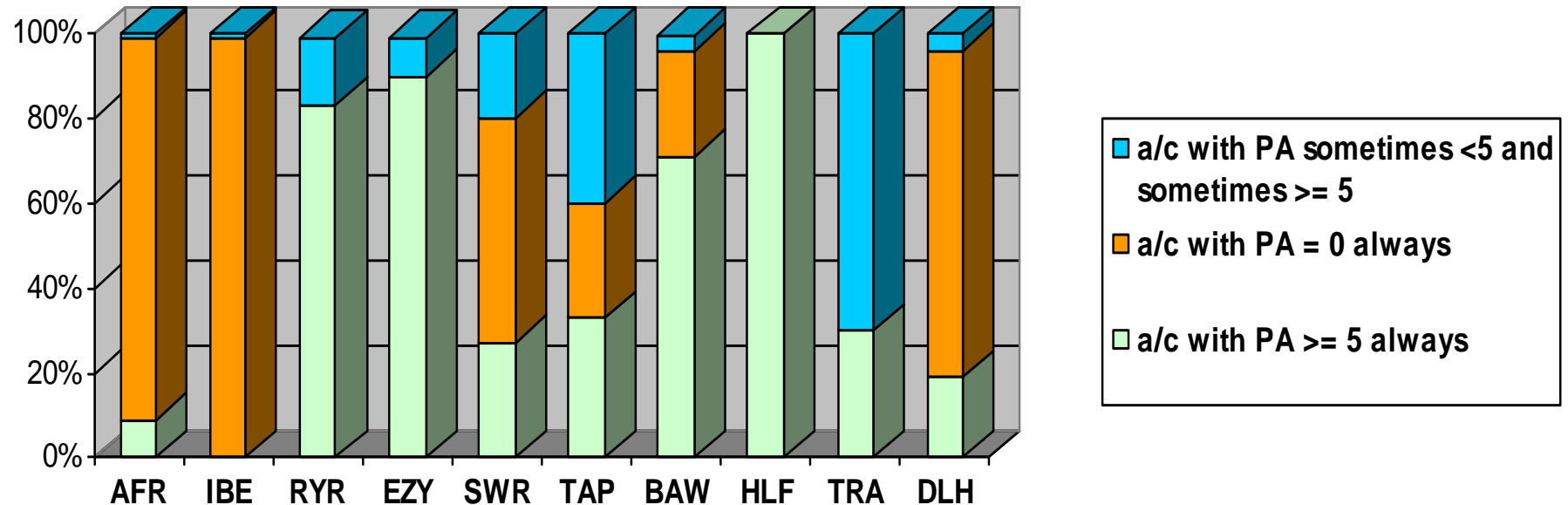
More than 90% of Air France, Ryan Air, EasyJet , Swiss Air and DLH callsigns could be correlated to an existing flight plan.

Comment: amongst the other airlines flying in Toulouse, lot of erroneous call sign (or no call sign at all) have been observed.

Some results – NUC versus airline



Data collection in Toulouse, France : May 05 – January 06



- More than 80% of Hapag Llyod (HLF), Ryan Air and EasyJet aircraft always report NUC (PA)>= 5.
- Conversely, more than 80% of Air France, Iberia and DLH aircraft always report NUC = 0.

Possible reasons for transmission of NUC = 0



Aircraft transmitting NUC always equal to 0 are not equipped with an appropriate architecture to receive GPS data (no GPS in the aircraft, no connection with a GPS engine or any other source for GPS data...)

The position data are coming from FMS or IRS, without integrity indicator (i.e. no GPS HPL)

Transmission of NUC = 0 is not an indication that the position is incorrect, but only an integrity indicator: “can I rely on the position of this aircraft?”

When aircraft airborne, the ground station is configured to automatically translate $NUC < 5$ to a $PA=0$ (i.e. discard the report)

When aircraft on ground, the ground station is configured to automatically translate $NUC \leq 6$ to a $PA=0$ (i.e. discard the report)

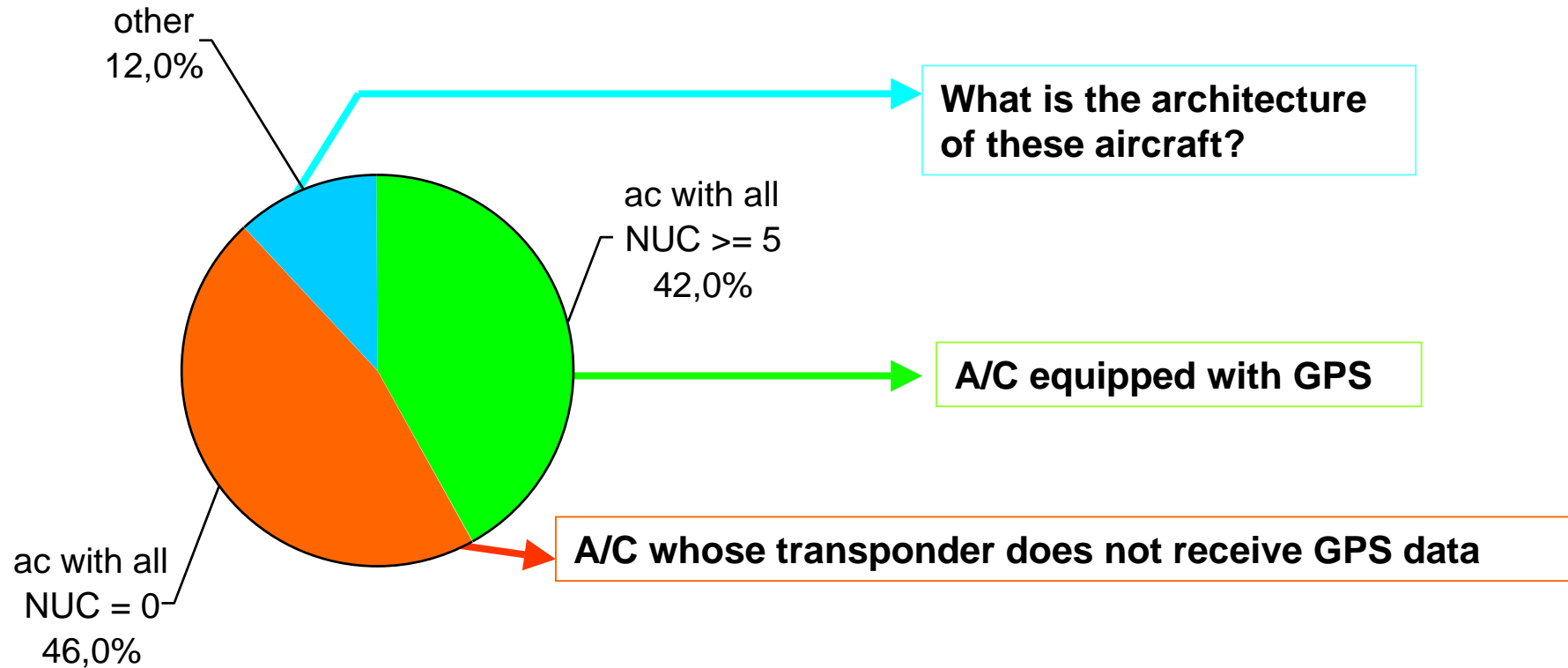
Opportunity Flights- Evaluation of integrity indicator



46% of aircraft always report NUC =0

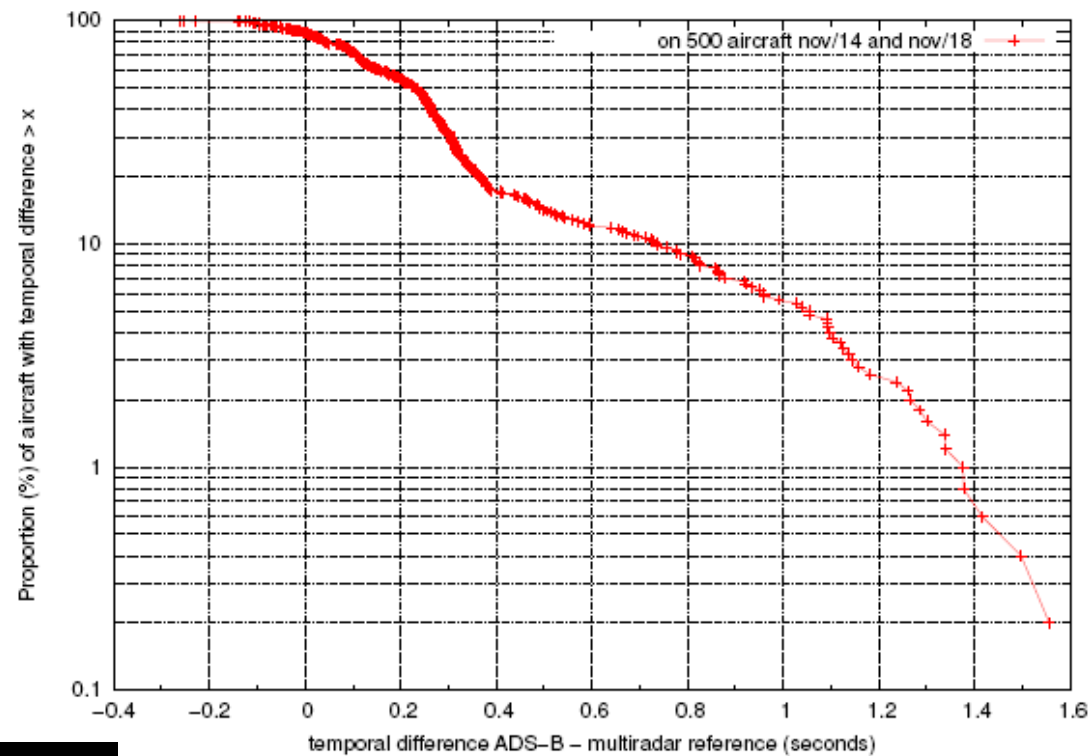
42% of aircraft always report NUC >5

12% of aircraft report both NUC >=5 and NUC < 5



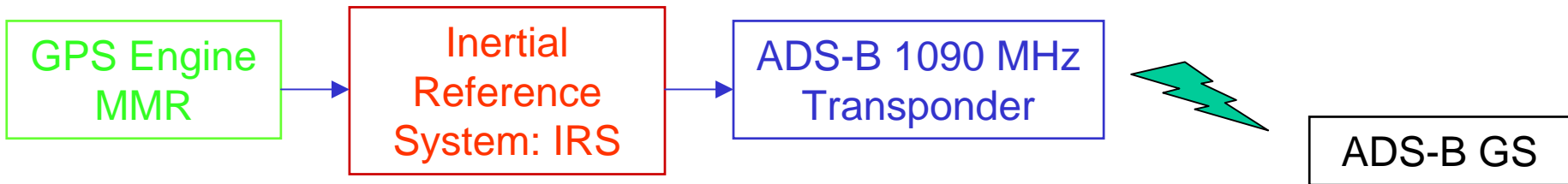
Note: a lot of aircraft reporting a NUC = 0 have, nevertheless, a very accurate navigation behaviour

On-board plus ground latency may reach 1.6s, in some instances.



Time deviations between ADS-B and smoothed multi-radar for all ADS-B reports on the 14/11 and 18/11, supposedly issued from GPS nav. Systems, measured individually per aircraft

Theoretical max position Latency



GPS sends position 1Hz

IRS transmits GPS position

XPDR extrapolates position

GS time stamping

Position calculation

IRS receives GPS position

XPDR receives GPS position

GS reception

Around 500 ms

500 ms

200 ms

10 ms

Time

This project:

- Allowed to collect large amount of air and ground data
- Was an opportunity to study avionics performance
- Provided data analysis to support airborne certification
 - It has been an input for European AMC-20-24
- Allowed to identify and analyse a number of issues such as onboard latency



Hong-Kong - 2007

Thales AS680 ADS-B Ground Station was mounted at the Tai Mo Shan, which is the highest mountain in Hong Kong (about 1000 metres above mean sea level)

SSR Antenna

ADS-B Antenna



Opportunity flights

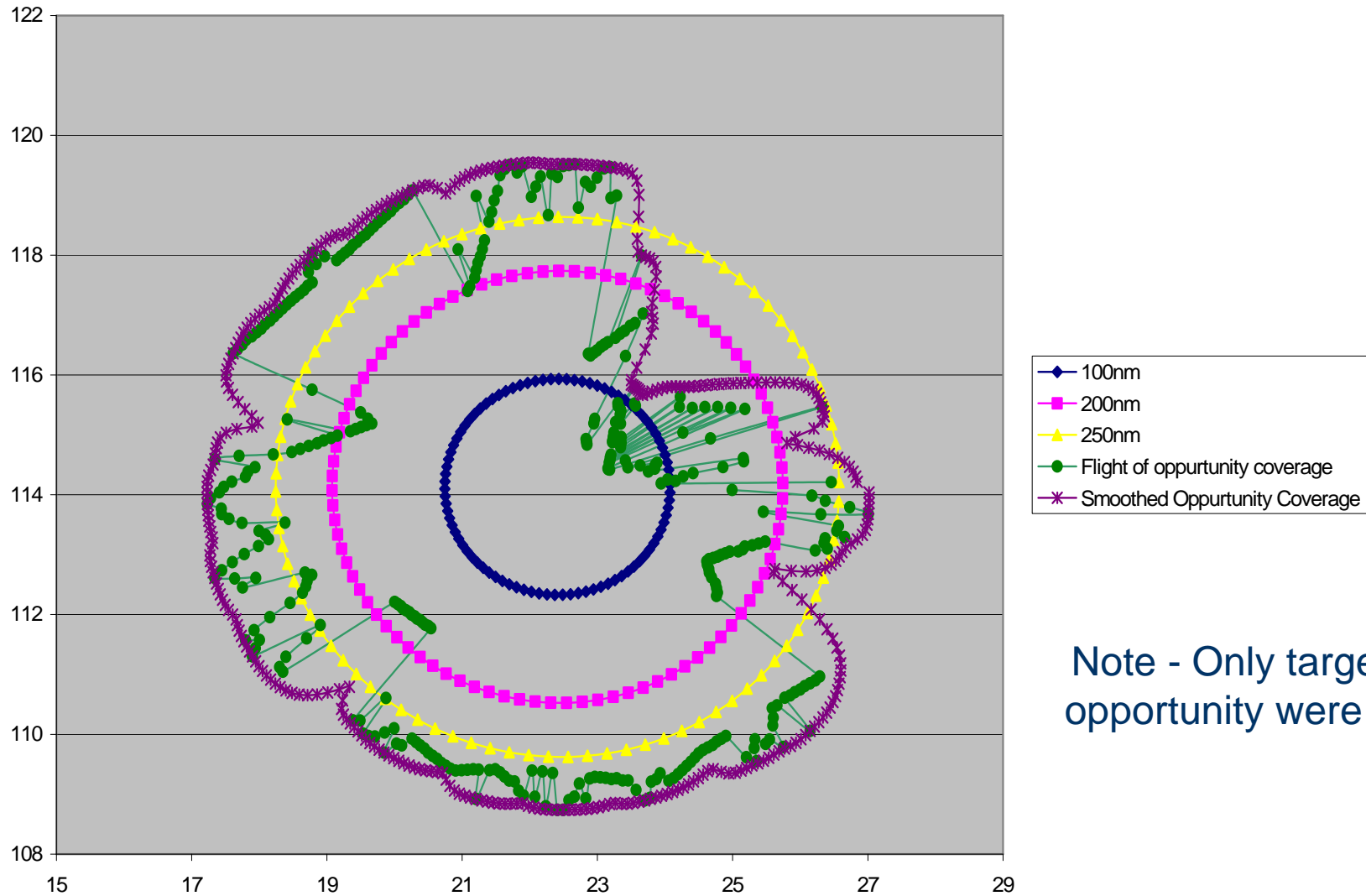
Slide courtesy of Civil Aviation Department, Hong Kong, China



- Data was subsequently analyzed to determine
 - coverage achieved
 - aircraft detected
 - flights detected
 - percentage of aircraft fitted with ADS-B
 - percentage of good position data transmitted (average NUC > 5)
- Visual comparison of ADS-B tracks vs SSR's
 - Displayed positions of ADS-B tracks and SSR's
 - velocity vectors derived from ADS-B and SSR

Slide courtesy of Civil Aviation Department, Hong Kong, China

Slide courtesy of Civil Aviation Department, Hong Kong, China



Note - Only targets of opportunity were used

ADS-B Detection Summary By Aircraft

Date	Number of ADS-B Equipped Aircraft	Number of ADS-B Aircraft with NUC > 5	Percentage of ADS-B Aircraft with NUC > 5	Number of ADS-B Aircraft with NUC <= 5	Percentage of ADS-B Aircraft with NUC <=5	Number of ADS-B Aircraft with NUC = 0	Percentage of ADS-B Aircraft with NUC = 0
5th April	475	321	67.58%	154	32.42%	72	15.16%
6th April	449	302	67.26%	147	32.74%	64	14.25%
7th April	517	322	62.28%	195	37.72%	88	17.02%
8th April	522	318	60.92%	204	39.08%	91	17.43%
9th April	518	335	64.67%	183	35.33%	85	16.41%
10th April	513	311	60.62%	202	39.38%	91	17.74%
11th April	521	382	73.32%	139	26.68%	85	16.31%
TOTAL	1028	670	65.18%	358	34.82%	182	17.70%

Note - Total not sum of days, as some aircraft detected on multiple days

Slide courtesy of Civil Aviation Department, Hong Kong, China

Points of Interest – Changing Callsign

Occasionally it was observed that an aircraft would broadcast multiple slightly different callsigns over the course of its flight.

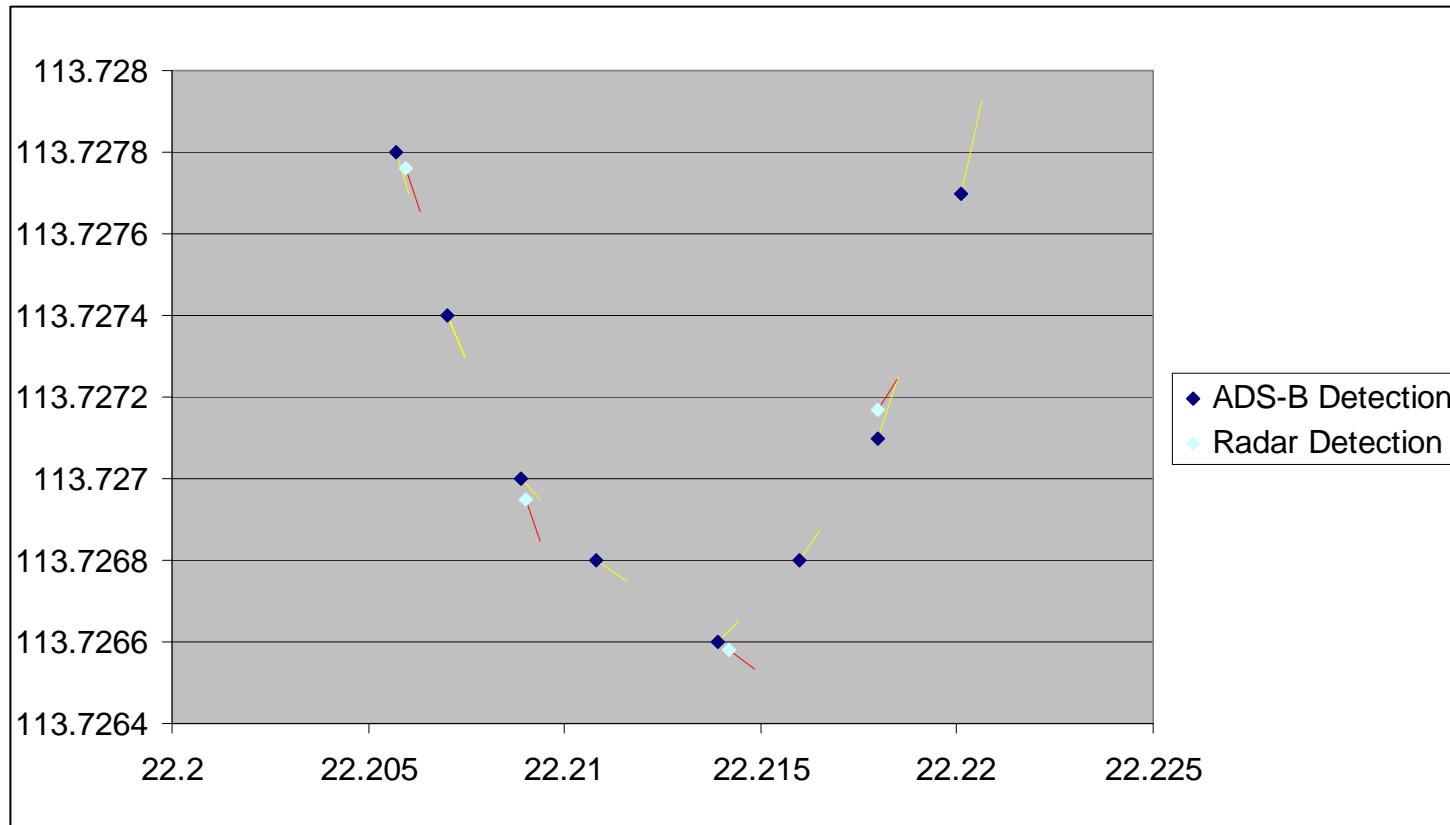
Should coupling on callsigns be used, this changing callsign would cause problems to the ATC system

Mode S ID	Callsign	SSR Code
484058	-	3123 5146
	KLM888	5146
	KLM888 0	5146
	KLM888 7	5146
	KLM888 E	5146
	KLM888 F	5146
	KLM888 H	5146
	KLM888 J	5146
	KLM888 N	5146
	KLM888 S	5146
	KLM888 U	5146
	KLM888 W	5146
	KLM888KL	5146
	KLM8LM88	3123 5146

Slide courtesy of Civil Aviation Department, Hong Kong, China

ADS-B velocity vector versus SSR

Slide courtesy of Civil Aviation Department, Hong Kong, China



ADS-B velocity vector appears much more accurate than radar's

- About 39% of aircraft were equipped with ADS-B capability
- Around 65% of these equipped aircraft were transmitting position data (NUC > 5)
- 18% of equipped aircraft were permanently transmitting NUC of “0”
- Changing call signs transmitted by aircraft may potentially cause problems to ATC system coupling
- In general, the ADS-B signal coverage at Tai Mo Shan can be up to 290NM at a certain altitude. Relocation of the ADS-B receiver to other site(s) will be considered to collect another set of data/observations
- Velocity vectors of ADS-B tracks are more accurate than Radar's
- Improved rate of ADS-B detections creates a more smooth track on sharp turns.

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ADS-B trial in Natuna, Indonesia – 2007 (DGAC Indonesia)

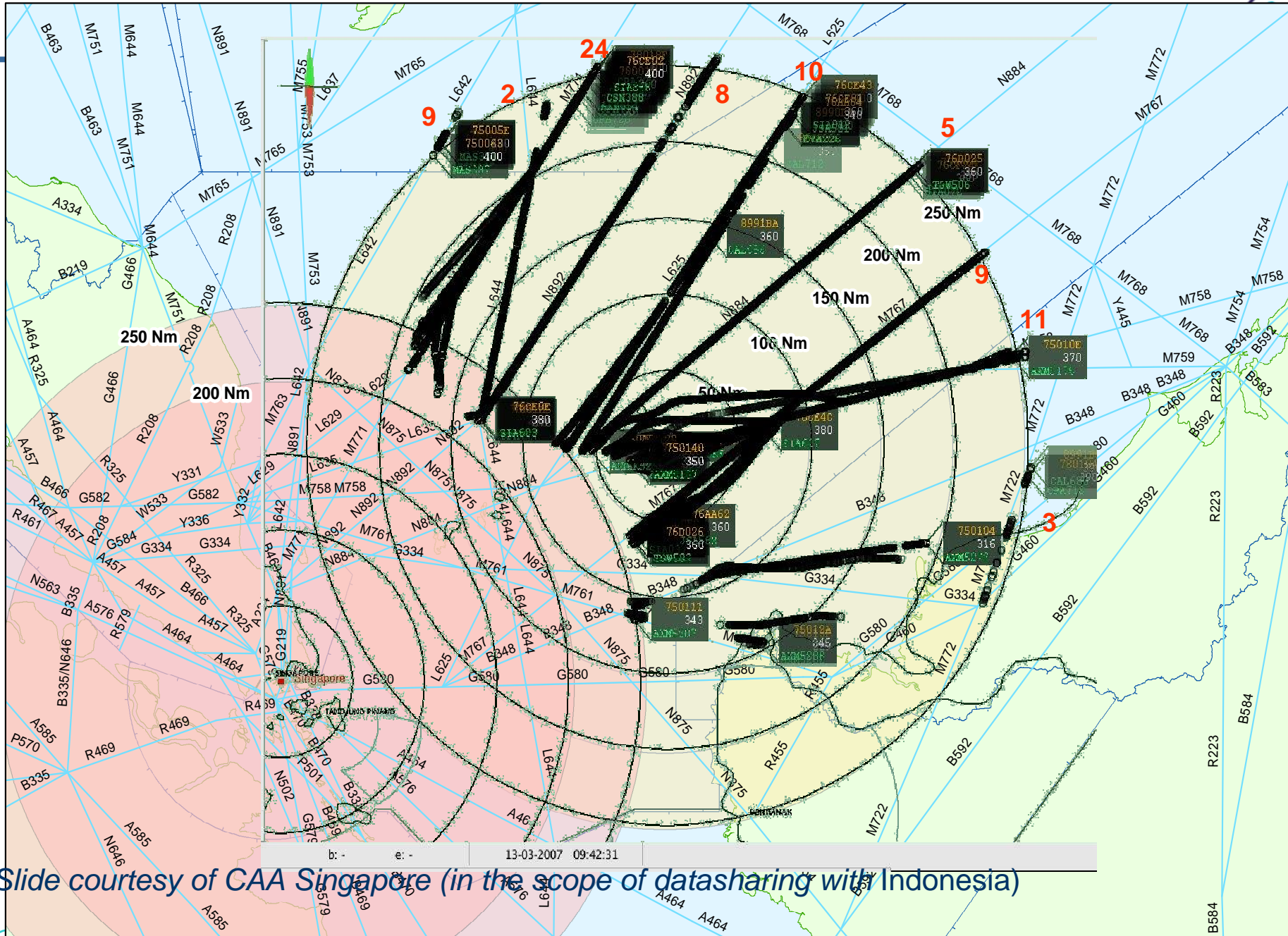
Trial objectives

- Coverage analysis
- Equipage analysis
- Navigational Uncertainty Category (NUC) analysis
- Probability of detection analysis
- Call signs reported by ADS-B
- Data sharing testing

Data Collection

- 48 hr period from 12 March 2007
- A total of 472,598 ADS-B messages were received from 394 aircrafts.

Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)



Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)

Location of ADS-B antenna



Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)

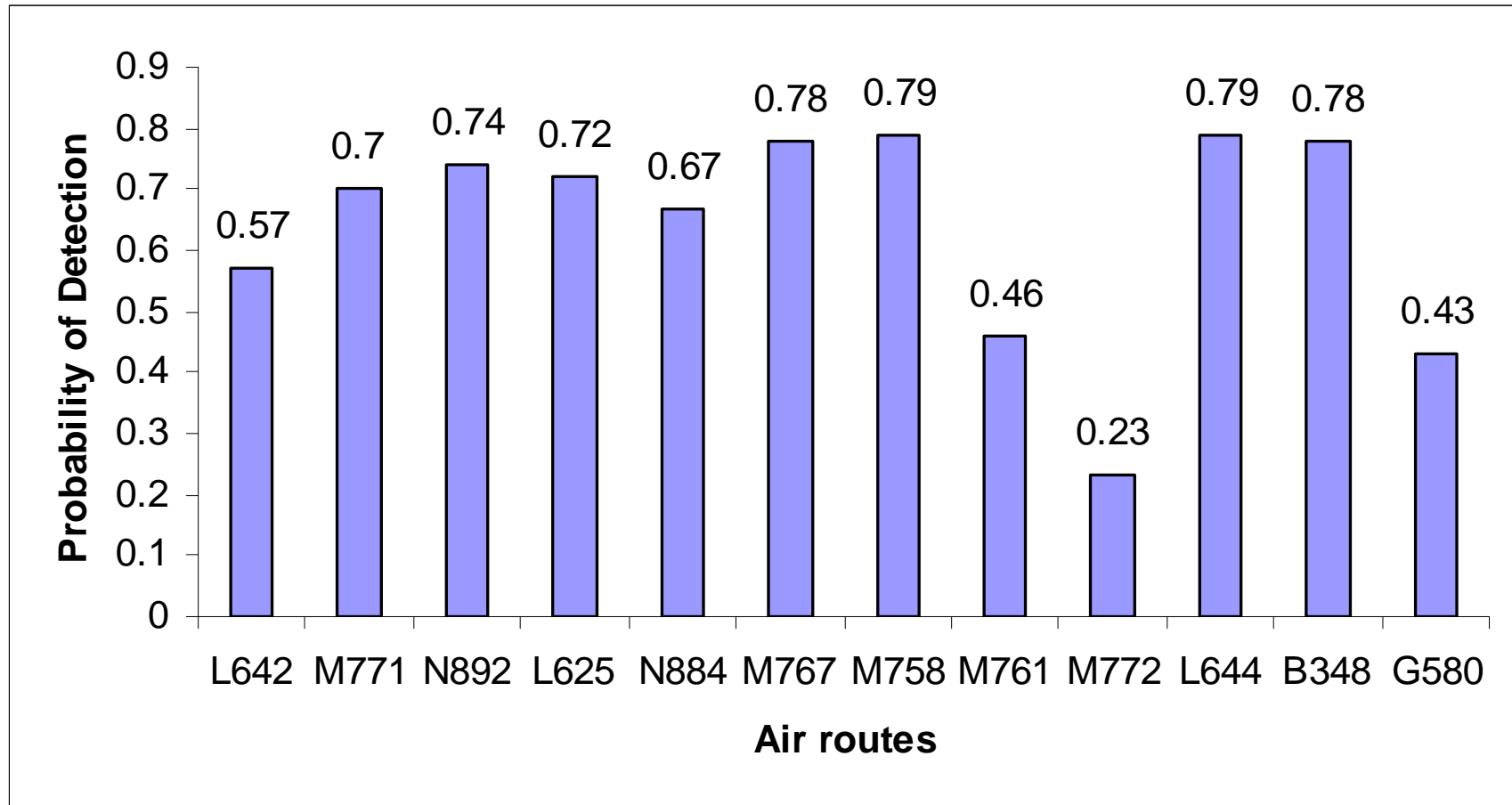
Total flights over the area: 911

Total flights recorded by ADS-B: 394

Percentage equipage: 43%

Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)

Probability of detection analysis



Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)

47 out of 394 flights reported wrong call-sign

Possible reasons:

- Pilots/crew forgot to enter callsign;
- Pilots/crew made mistakes when keying callsign;
- Confusion over IATA and ICAO callsigns.

Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)

ADS-B reported call sign

Callsign	24-bit code	Route	FL	Actual Callsign
-	89904F	N892	390	EVA6207
AK5156	750105	M758	370	AXM5156
AK5108	750106	M758	370	AXM5108
852	7BB136	M771	360	CXA852
5J547	75804B	M767	360	CEB547
5J803	75805F	M767	360	CEB803
KAL0353	71BC99	N892	360	KAL353
KAL0367	71BE00	N892	360	KAL367
5J548	75804B	N884	380	CEB548
5J804	75805F	N884	360	CEB804
GA896	8A0037	M771	400	GIA896
AK5254	750129	M758	270	AXM5254
CA958	780291	M771	360	CCA958
AK5255	750129	M758	280	AXM5255
PR503	758064	M767	360	PAL503
MH390	75005D	M771	360 - 380	MAS390
MI924	76CD89	M771	340	SLK924

Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)

Results could support the use of ADS-B for ATC operation on the 6 parallel RNP-10 routes of the South China Sea

Coverage can be further improved by adding or relocating ADS-B sensors.

Pilots/crew should be instructed to key in ICAO call signs.

Slide courtesy of CAA Singapore (in the scope of datasharing with Indonesia)



Conclusion



Trials set-up in various plaes of the world allowed to assess the overall performances of ADS-B:

- **Percentage of aircraft equipped**
- **Percentage of aircraft broadcasting correct ADS-B data**
- **Measurement of update rate, NUC distribution**
- **Analysis of Call Sign correctness**

In addition ADS-B trials represent an opportunity for testing across FIR data sharing, which definitely can enhance safety and efficiency.

As already achieved in Europe and Asia, Thales is ready to support CAAs of Latin America for the preparation of ADS-B trials.



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Horizontal Protection Level

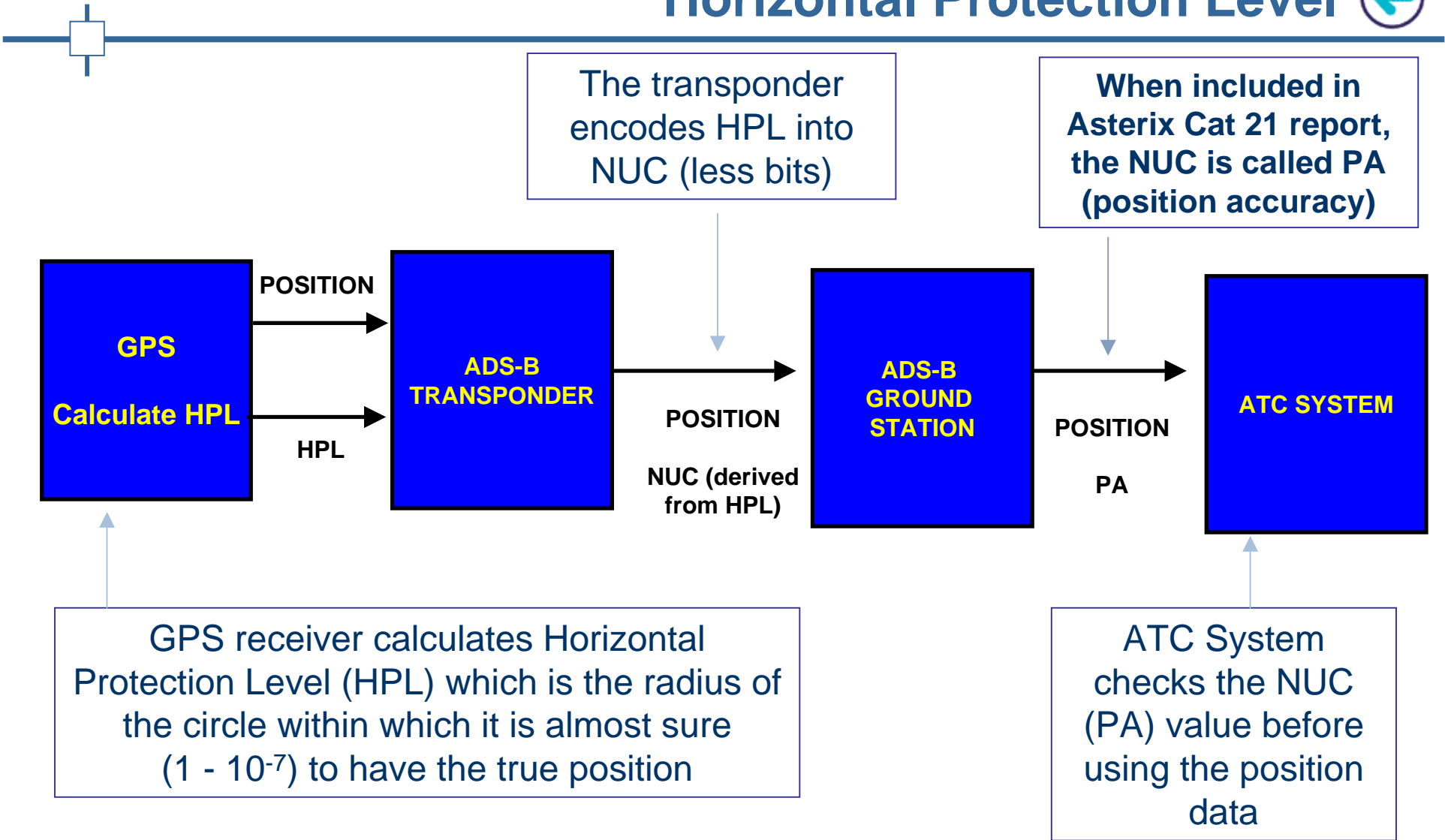


Figure Of Merit (FOM) represents the accuracy of the position measurement by the GPS receiver

This term is sometimes incorrectly used to designate NUC or PA (=> brings confusion)

In the updated version of transponder standard (i.e. DO260A), NUC has been replaced by 3 parameters:

- NIC (Navigation Integrity category) <-> HPL
- NAC (Navigation Accuracy Category) <-> FOM
- SIL (System Integrity Level) : related to airborne configuration, indicates the level of Integrity (i.e. 10-7, 10-5 or 10-3)

Definition Of NUC

Table 2-11: “TYPE” Subfield Code Definitions (DF = 17 or 18)

Type Code	Format	Horizontal Protection Limit, HPL	95% Containment Radius, μ and ν , On Horizontal and Vertical Position Error	Altitude Type	NUC_P
0	No Position Information			Baro Altitude or No Altitude Information	0
1	Identification (Category Set D)			<i>Not Applicable</i>	
2	Identification (Category Set C)			<i>Not Applicable</i>	
3	Identification (Category Set B)			<i>Not Applicable</i>	
4	Identification (Category Set A)			<i>Not Applicable</i>	
5	Surface Position	HPL < 7.5 m	$\mu < 3$ m	No Altitude Information	9
6	Surface Position	HPL < 25 m	3 m $\leq \mu < 10$ m	No Altitude Information	8
7	Surface Position	HPL < 185.2 m (0.1 NM)	10 m $\leq \mu < 92.6$ m (0.05 NM)	No Altitude Information	7
8	Surface Position	HPL ≥ 185.2 m (0.1 NM)	(0.05 NM) 92.6 m $\leq \mu$	No Altitude Information	6
9	Airborne Position	HPL < 7.5 m	$\mu < 3$ m	Baro Altitude	9
10	Airborne Position	7.5 m \leq HPL < 25 m	3 m $\leq \mu < 10$ m	Baro Altitude	8
11	Airborne Position	25 m \leq HPL < 185.2 m (0.1 NM)	10 m $\leq \mu < 92.6$ m (0.05 NM)	Baro Altitude	7
12	Airborne Position	185.2 m (0.1 NM) \leq HPL < 370.4 m (0.2 NM)	92.6 m (0.05 NM) $\leq \mu < 185.2$ m (0.1 NM)	Baro Altitude	6
13	Airborne Position	380.4 m (0.2 NM) \leq HPL < 926 m (0.5 NM)	185.2 m (0.1 NM) $\leq \mu < 463$ m (0.25 NM)	Baro Altitude	5
14	Airborne Position	926 m (0.5 NM) \leq HPL < 1852 m (1.0 NM)	463 m (0.25 NM) $\leq \mu < 926$ m (0.5 NM)	Baro Altitude	4
15	Airborne Position	1852 m (1.0 NM) \leq HPL < 3704 m (2.0 NM)	926 m (0.5 NM) $\leq \mu < 1.852$ km (1.0 NM)	Baro Altitude	3
16	Airborne Position	7.704 km (2.0 NM) \leq HPL < 18.52 km (10 NM)	1.852 km (1.0 NM) $\leq \mu < 9.26$ km (5.0 NM)	Baro Altitude	2
17	Airborne Position	18.52 km (10 NM) \leq HPL < 37.04 km (20 NM)	9.26 km (5.0 NM) $\leq \mu < 18.52$ km (10.0 NM)	Baro Altitude	1
18	Airborne Position	HPL ≥ 37.04 km (20 NM)	18.52 km (10.0 NM) $\leq \mu$	Baro Altitude	0
19	Airborne Velocity	<i>Not Applicable</i>	<i>Not Applicable</i>	<i>Difference between “Baro Altitude” and “GNSS Height (HAE)”</i>	<i>N/A</i>
20	Airborne Position	HPL < 7.5 m	$\mu < 3$ m and $\nu < 4$ m	GNSS Height (HAE)	9
21	Airborne Position	HPL < 25 m	$\mu < 10$ m and $\nu < 15$ m	GNSS Height (HAE)	8
22	Airborne Position	HPL ≥ 25 m	$\mu \geq 10$ m or $\nu \geq 15$ m	GNSS Height (HAE)	TBD

