



SURVEILLANCE & ATM SYSTEMS :

The use of ADS-B data by ATM

ICAO Surveillance Seminar for the NAM/CAR/SAM

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Surveillance is a key function of ATM systems

It allows to provide the controller with a reliable, up-to-date representation of the current air situation

The basis of modern surveillance is radar. However new systems and technologies allow alternate choice or to complement current means for better performance

Mode-S radar, ADS-B and WAM are enablers to various ATM applications allowing for improvements to safety and capacity of airspace

The choice of surveillance means should depend on:

- Operational environment (phase of flight, traffic density)
- Cost aspects
- Benefits to both Airlines and ANSPs

For new systems a number of issues related to their implementation need to be considered as well :

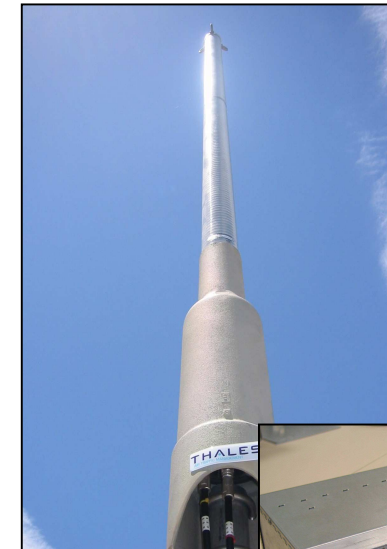
- Regulatory aspects
- Safety and security requirements
- Airborne Equipment certification Status (e.g. ADS-B)

Surveillance in ATM Automation Systems



The introduction of new surveillance means provides scope for enhancing the current surveillance and alert capabilities of ATM systems

- Surveillance accuracy is improved
- Existing alert functionality may be enhanced, and new alerts may be defined
- New supporting tools for the controller can be defined



THALES



New surveillance means include:

ADS-C

→ Position (oceanic or desertic, low update rate)

ADS-B

→ Position (continental, high to medium update rate)

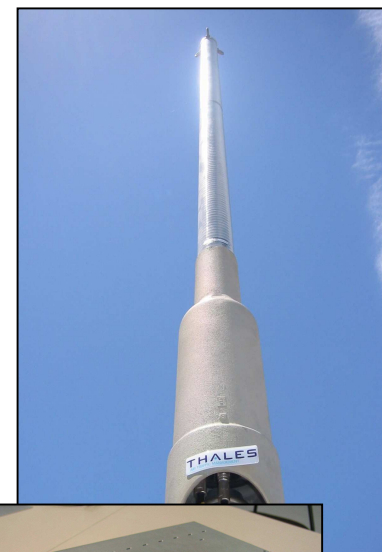
→ Derived Aircraft Parameters (DAP)

Wide Area Multilateration

→ Position (continental, high to medium update rate)

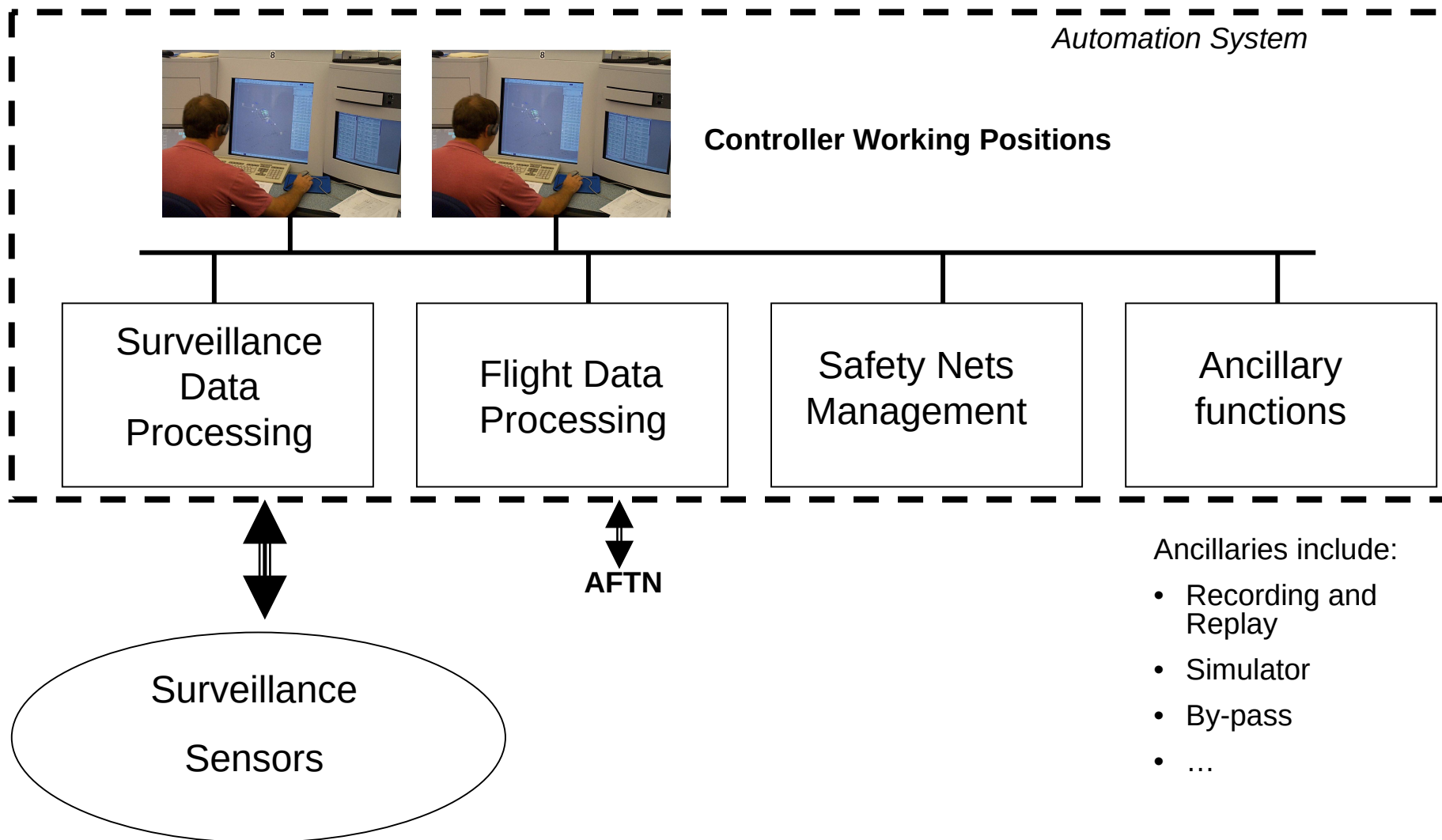
Mode S radar

→ Derived Aircraft Parameters (DAP)



The impact of integrating a new surveillance in a generic ATM system varies with the surveillance means

Functional architecture of an automation system

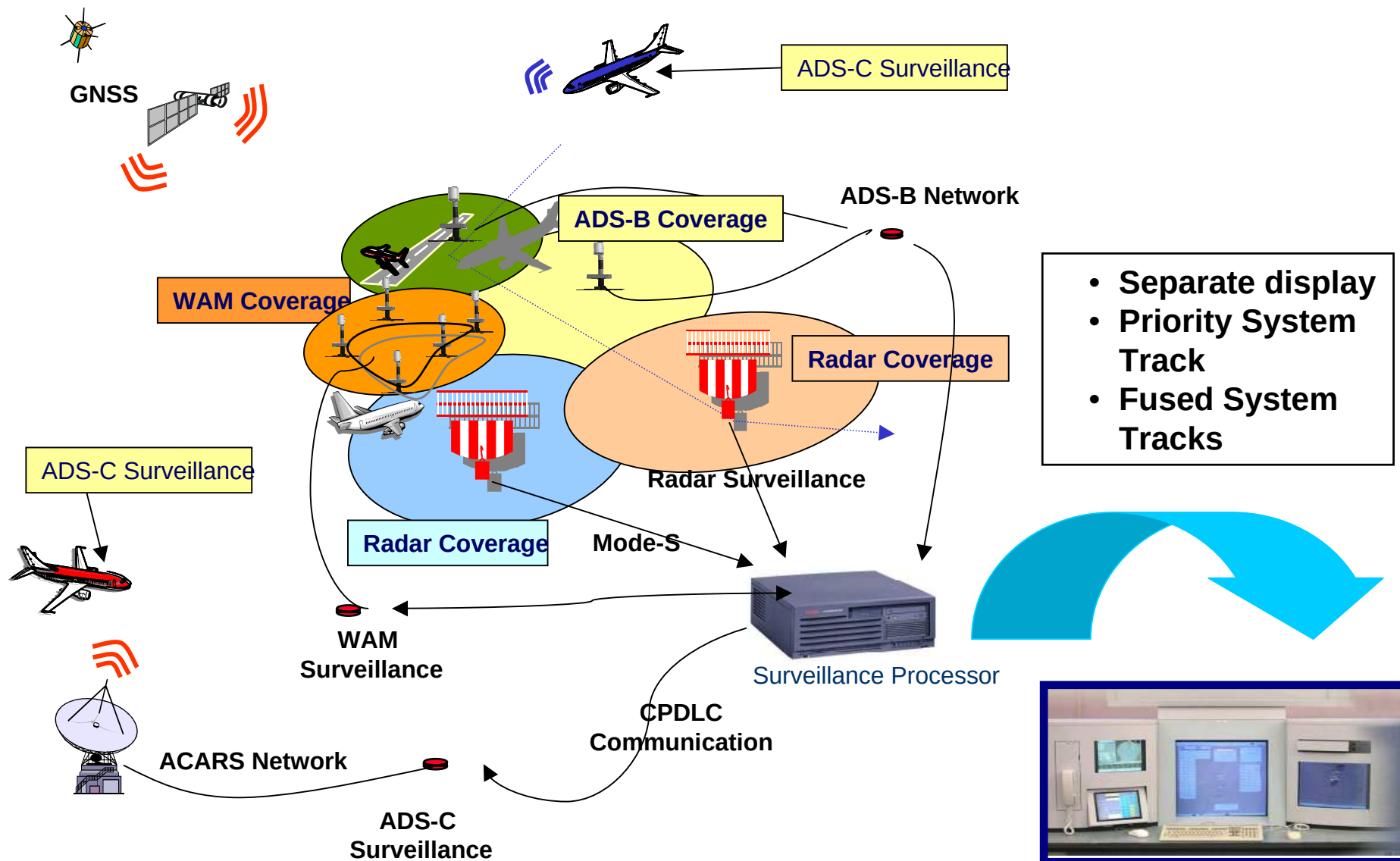




Considering new surveillance technologies has an impact on the ATM System

- **A new surveillance source will impact the elaboration of the air situation**
 - Surveillance processing function (eg tracking)
 - Controller Working Position (eg target symbol)
- **Data link capabilities (Derived Aircraft Parameters) will impact the elaboration of the air situation, alerts capability, controllers tools**
 - Surveillance processing function (eg tracking)
 - Alerts management function
 - Controller Working Position (eg target symbol, target data)
- **Depending on the capabilities and age of the ATM system, the solution to integrate new surveillance means may vary**

Improve surveillance : Multi Sensor Tracking System





A separate display for each technology

- Not desirable for operational use (the controller has to perform a mental integration)
- Has been used for demonstration or to build operational experience before further integration is performed

A priority system

- One means (or data from a particular site) is displayed and other data sources discarded whilst the priority source provides useable data
- Facilitates the safety case (surveillance data streams are well separated)

A fully fused position calculation

- Data from different means are used to calculate a best estimate of aircraft position
- Better performance
- Better use of the assets



Stand Alone Display

Aside the current Controller Working Position (CWP) install a « technical display » showing tracks obtained by a new surveillance means

→ eg ADS-B tracks for an area non covered by radar

Pros:

→ Limited cost

→ Might be suitable as interim solution for very low traffic density

Cons:

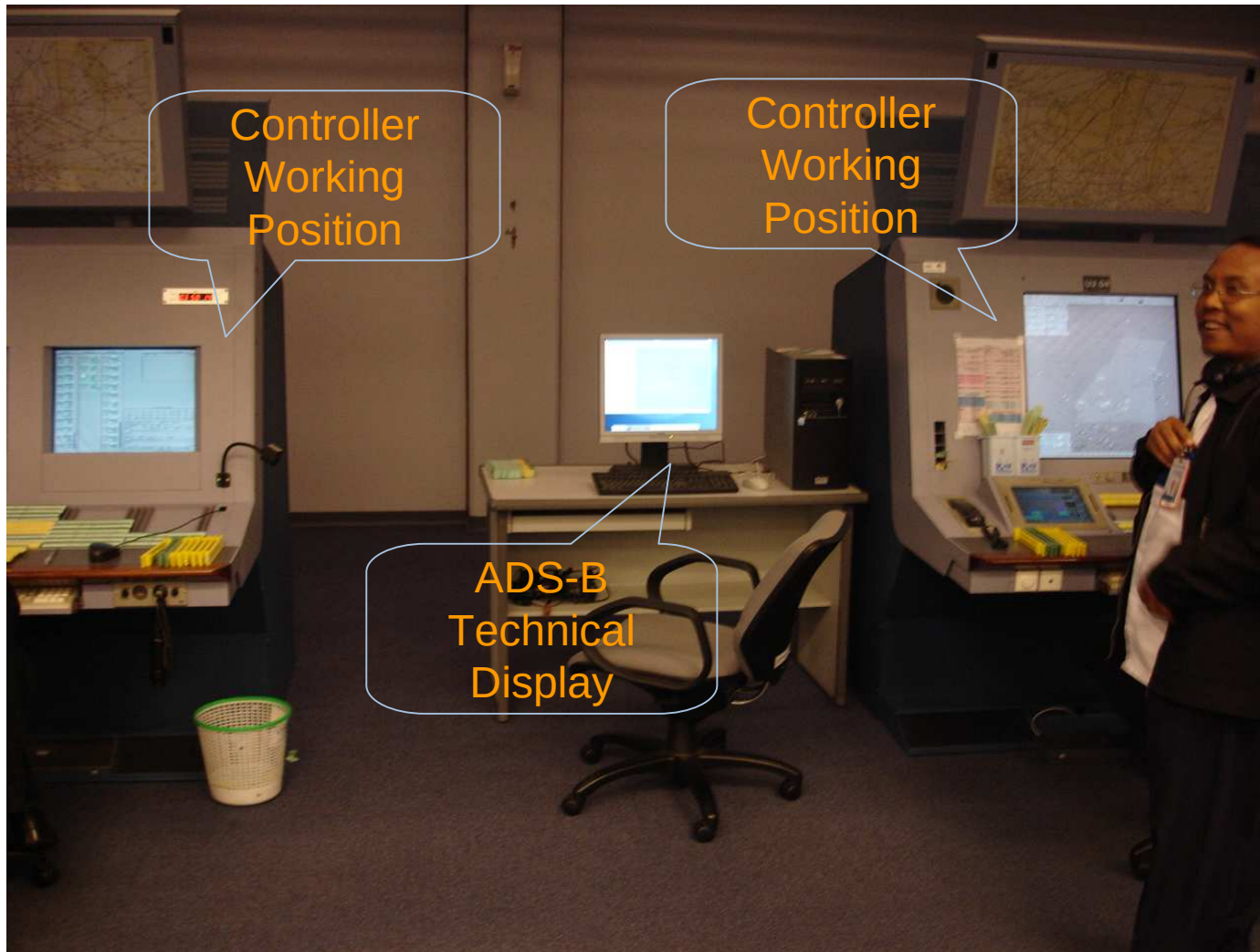
→ Controller has to perform mental integration of Air Situation

→ No or limited safety net function

→ No coupling with flight plan data

→ Generally technical displays are not designed for ATCO operations

Example – ADS-B Operational Trial in Indonesia



Not very convenient to locate ADS-B Display close to CWP



Priority Tracks Display

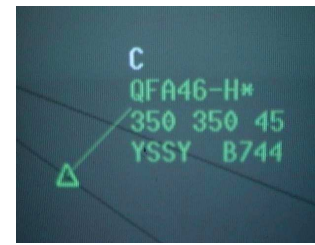
Principle of priority tracks system



Radar Tracks



ADS - B tracks



ADS- C tracks
(FANS1/A datalink)



Flight Plan
tracks

If an aircraft is seen by a radar, the displayed track will be based on radar even if the ADS-B information is available for this aircraft

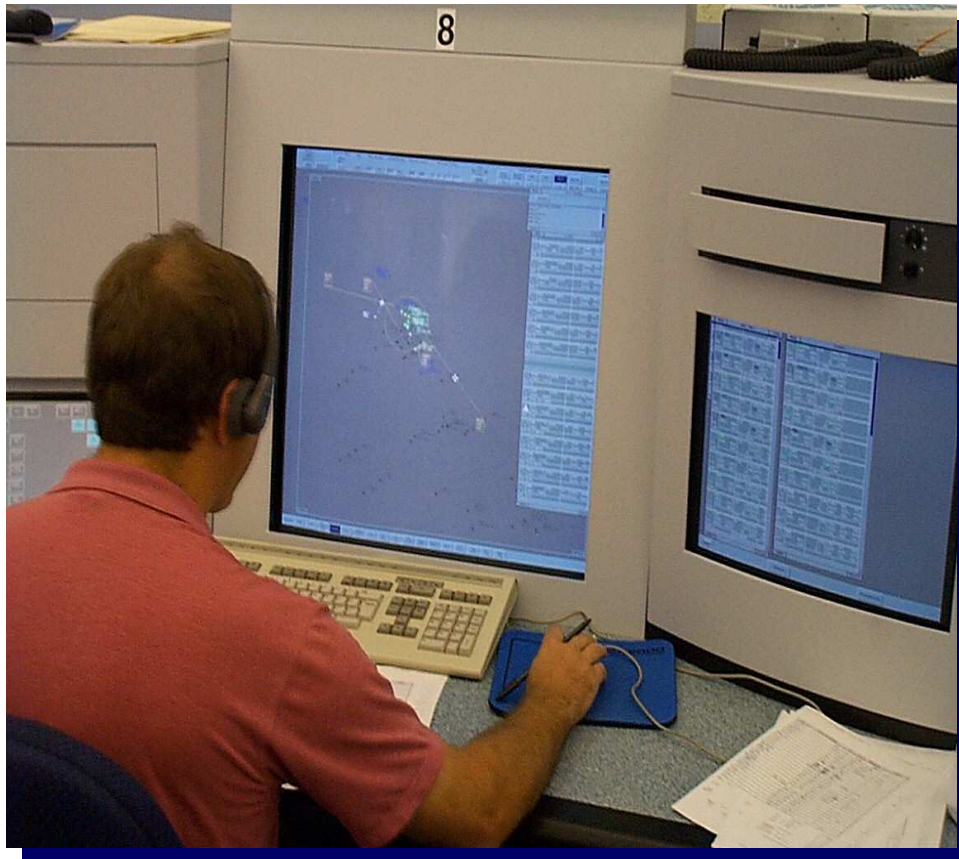
Then this principle can be applied for several surveillance sources:

- Priority 1: Radar
- Priority 2: ADS-B (or WAM)
- Priority 3: ADS-C
- Priority 4: Flight Plan



Fused Tracks Display

A fused track system makes the best estimate from available surveillance sources



Fused System Tracks

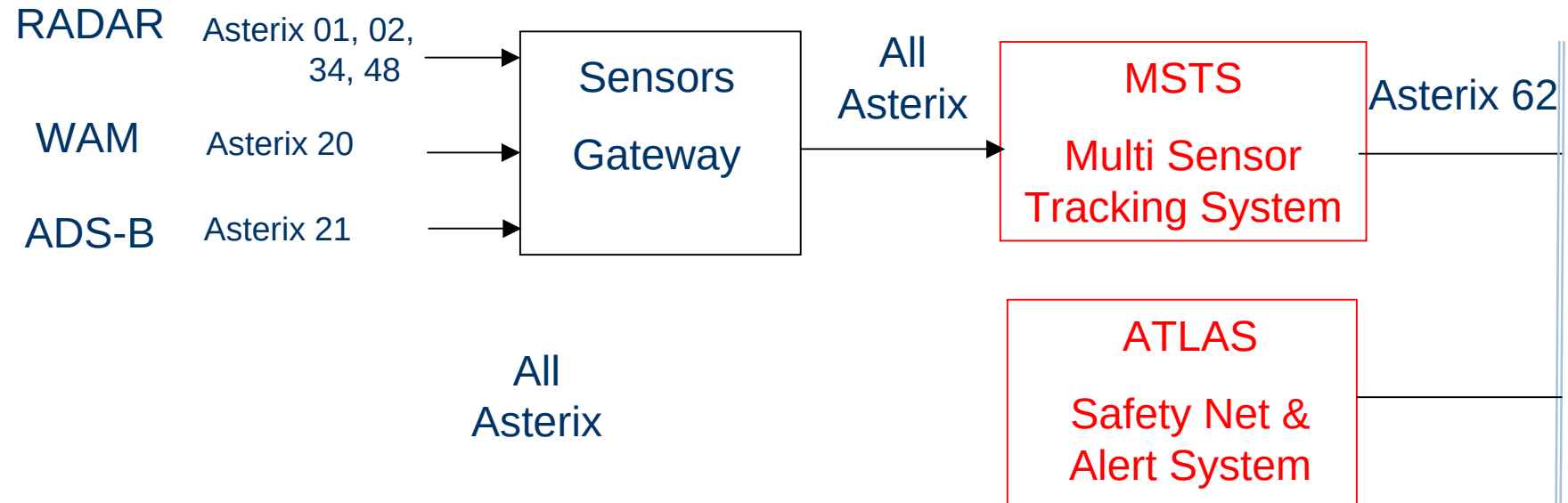
- single system track for all sensors
- fusion of all relevant downlinked data
- more accurate tracking

New surveillance architecture = data fusion

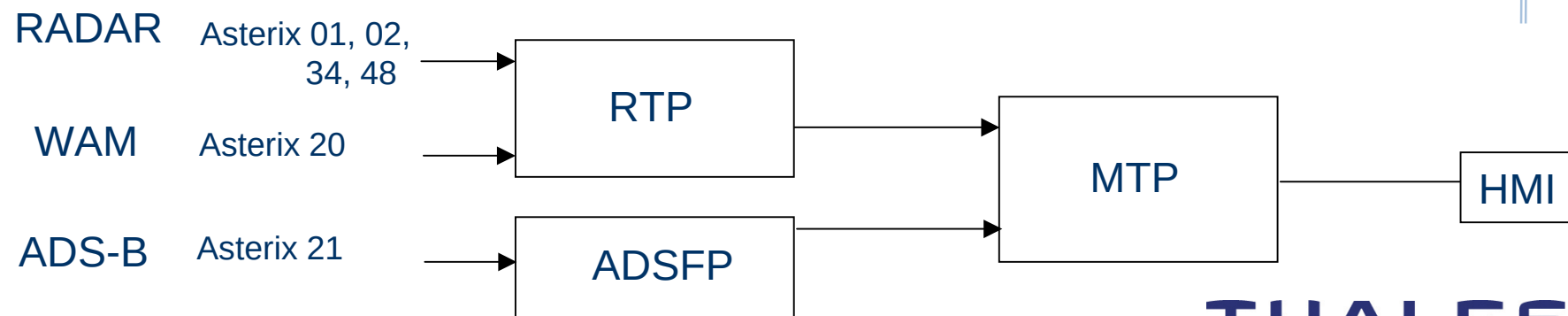


Operational system

LANs



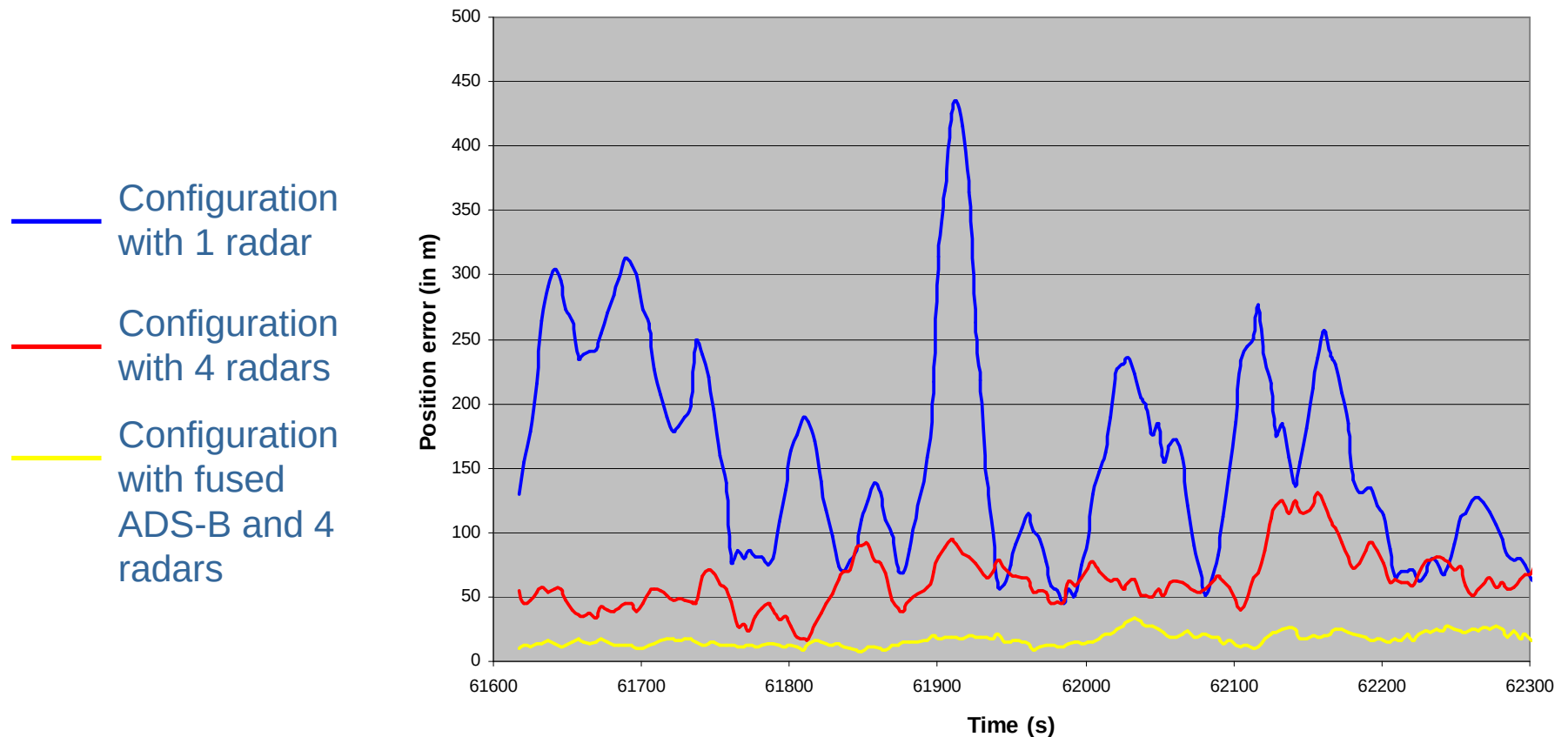
Fall-Back/Bypass system



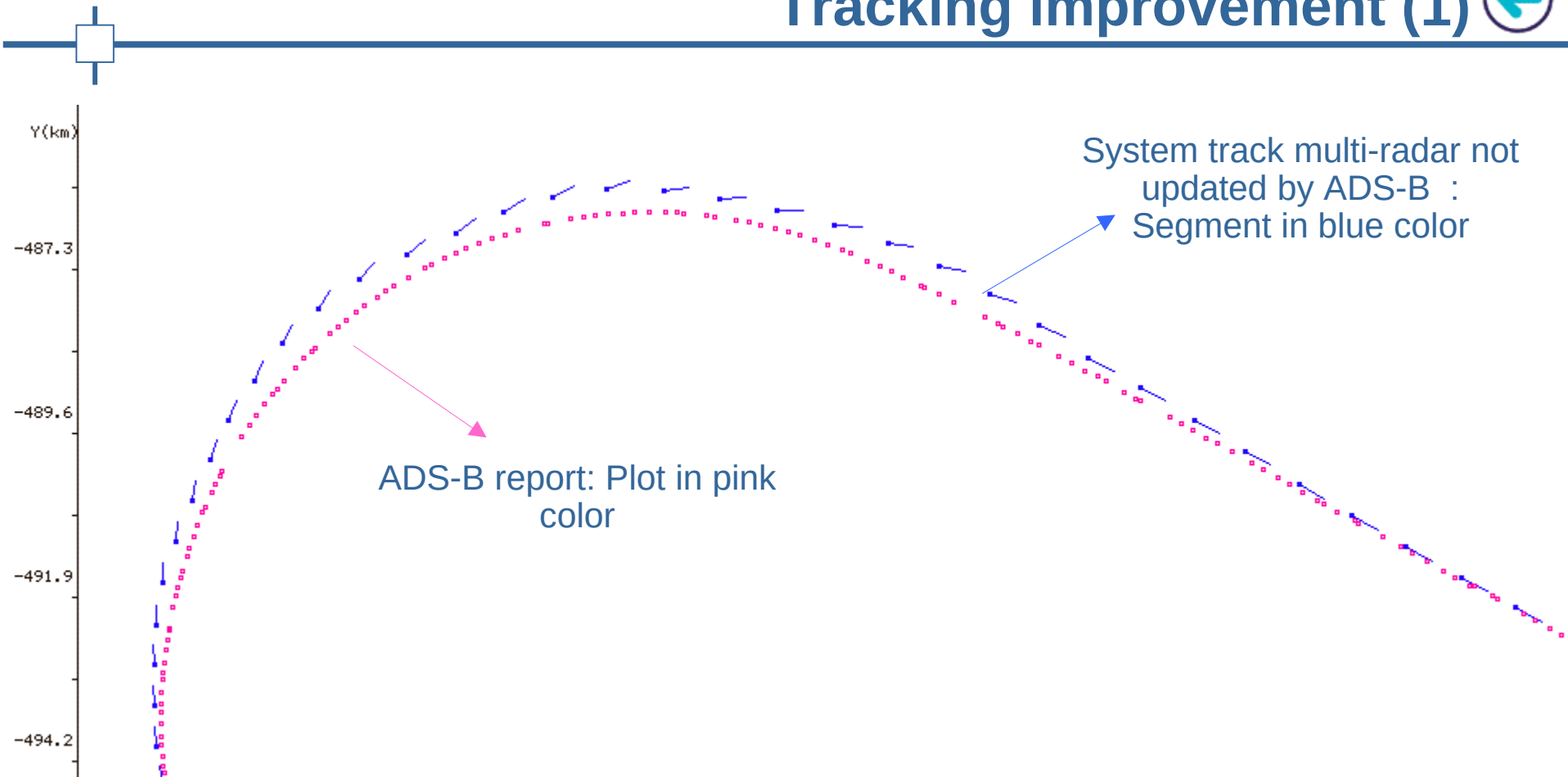
Tracking performance - Example



Position error on simulated scenario

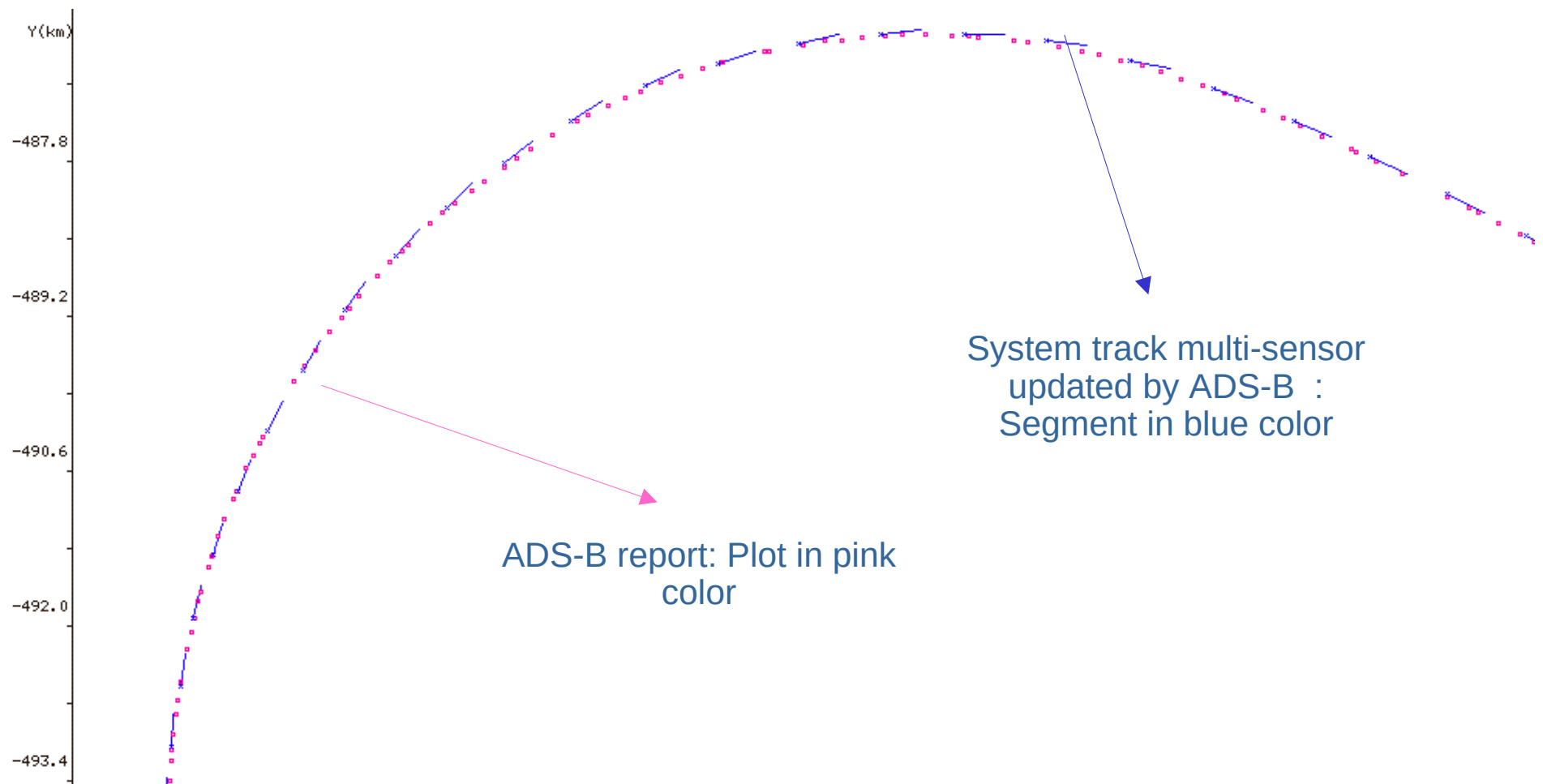


Tracking improvement (1)



Cap Town: Multi-Radar tracking

Tracking improvement (2)



Cap Town: Multi sensor (ADS-B+Radar) tracking



New surveillance technologies such as ADS-B and Mode-S include additional data on top of the traditional state vector provided by Radar and Multilateration

So-called Derived Aircraft Parameters (DAP)

This includes:

- FMS Selected Level
- Track and turn reports
- Heading and speed reports
- Intent data
- ACAS Resolution Advisories
- Meteorological data



Trajectory Prediction can be made more accurate
Existing Safety Nets can be made more reactive
Potential for new type of alerts

Multiple Surveillance Data and DAP allow to enhance existing functions or add new functions

Existing alert functionality may be enhanced:

- Short Term Conflict Alert
- Cleared Level Monitoring
- Route Adherence Monitoring
- Minimum Safe Altitude Warning and
- Danger Area Infringement Warning



New alerts may be defined:

- Inconsistency between data from various surveillance sources
- Inconsistency between surveillance data and flight plan data

Controller Access Parameters : display DAP to the controller

Improvement of Trajectory Prediction (improvement of Flight Plan prediction)

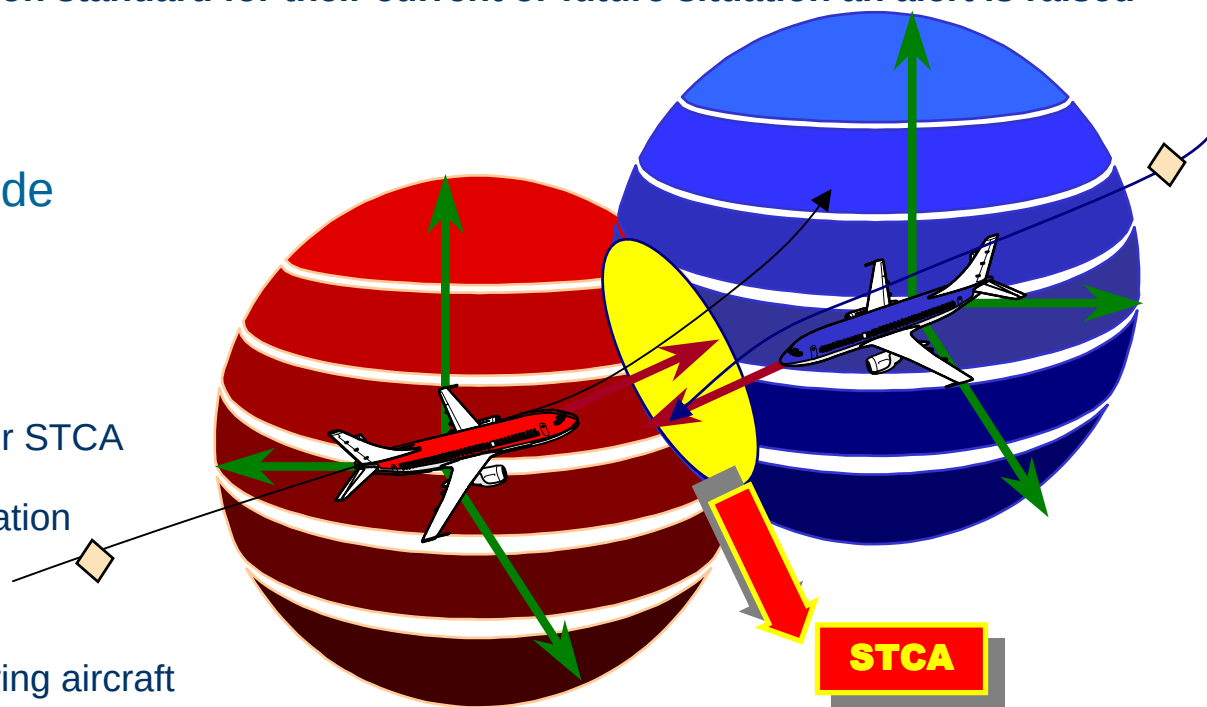


Short Term Conflict Alert

The short-term conflict alert performs a linear extrapolation of the current position of aircraft based on their current speed and heading in order to predict their future positions. If the aircraft are going to violate a separation standard for their current or future situation an alert is raised

ADS-B and MLAT data will provide

- Improved rate of update
- Quicker STCA Detection
- Reduced tolerance's required for STCA
- Improved velocity vector information
- Rate of Turn information
- Less false STCAs for maneuvering aircraft



Together this will provide an improved STCA for EnRoute and a quality STCA for Approach.

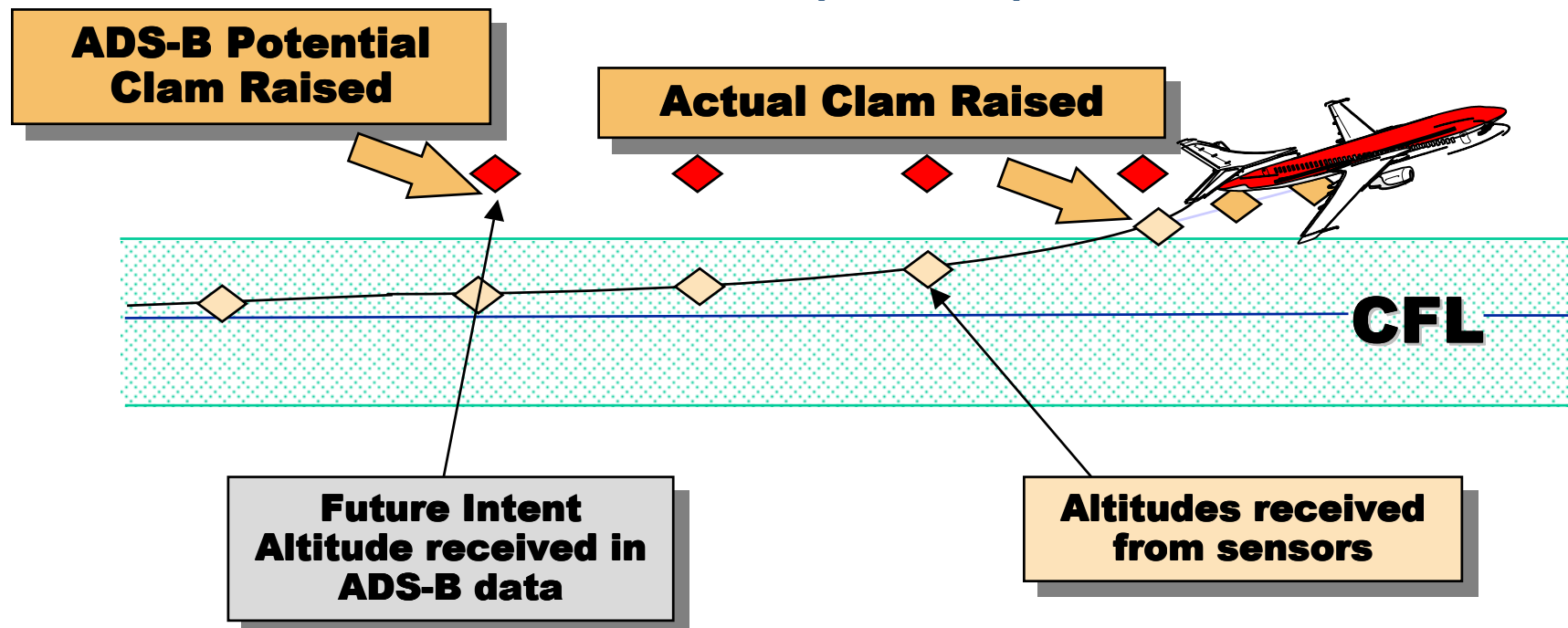


Cleared Level Adherence Monitoring

ADS-B data received from an aircraft can include

- Intermediate State Selected Altitude
- Final State Selected Altitude data

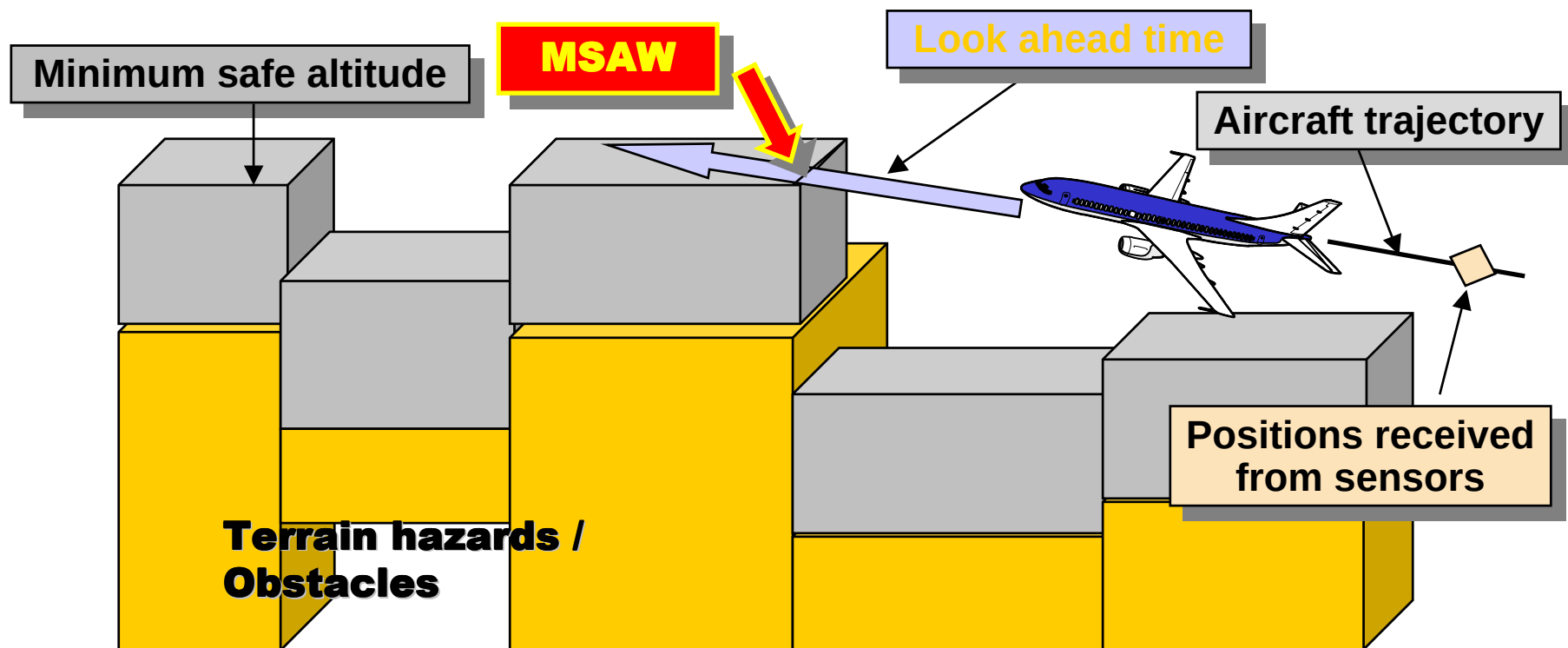
This data immediately gives information about the intent of the pilot and can alert the controller to a potential problem much earlier





Minimum Safe Altitude Warning

Minimum Safe Altitude Warning can be improved in the same way as the Cleared Level Alert is improved by ADS-B intent information, and by the use of ADS-B Rate of Climb information.





Inconsistency aircraft received data & aircraft derived data

It is anticipated that the prime area for deriving new alerts in an ADS-B environment is in the **comparison between ADS-B data and other surveillance data.**

Today many aircraft are detected simultaneously by radar and ADS-C transmissions. Soon aircraft will also be detected by ADS-B transmissions. The variety of sensor types provide multiple sources of data for the same aircraft.

With surveillance data fusion becoming more prominent, an essential part of the process will be checking the data for inconsistencies during this fusion procedure.



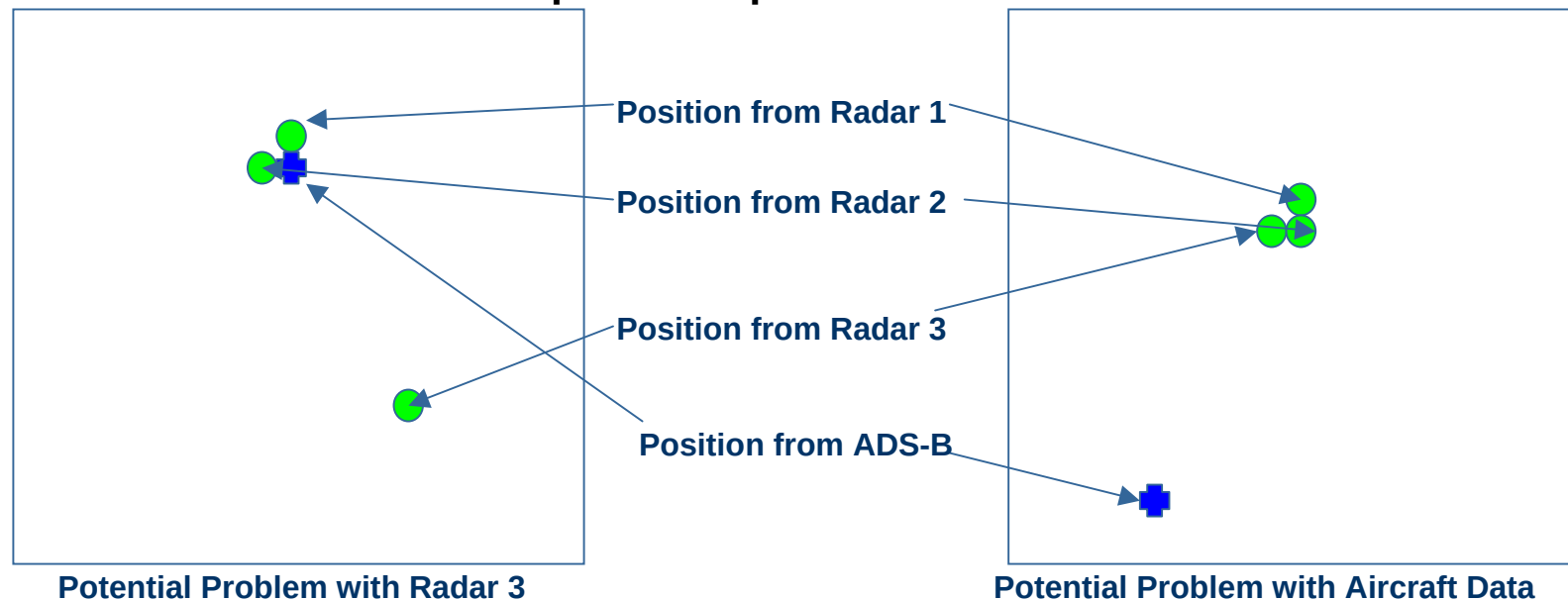
The simplest new alert will highlight inconsistencies between the derived and received position of the aircraft.

- This alert must have the capability to attempt to determine if the sensor or the aircraft position is incorrect.

Received data such as speed, heading or altitude can also be checked.

- One of the most useful new alerts could be the checking of reported versus measured speed of an aircraft.

Example : Multiple Radar Environment



NEW ALERTS: Inconsistency aircraft received data & flight plan data



The other source for deriving new alerts is in the comparison of ADS-B data and flight plan data registered in the ATM system.

- ARCW (Aircraft Route Conformance Warning) checks already the received ADS-C route data (which is entered in the Flight Management System of the aircraft) against the flight plan data entered in the ATM system, and can identify a possible problem well before it occurs.
- This can be readily expanded to include ADS-B data by comparing received ADS-B trajectory intent information against the flight plan data to determine if there are any inconsistencies.

However, new surveillance technologies permit new types of alerts. For example, the ADS-B emitter category can be checked against the stored flight plan data.

- The controller believes he is in communication with a light aircraft when in fact it is a heavy aircraft. This could result in the controller giving the aircraft incorrect instructions.



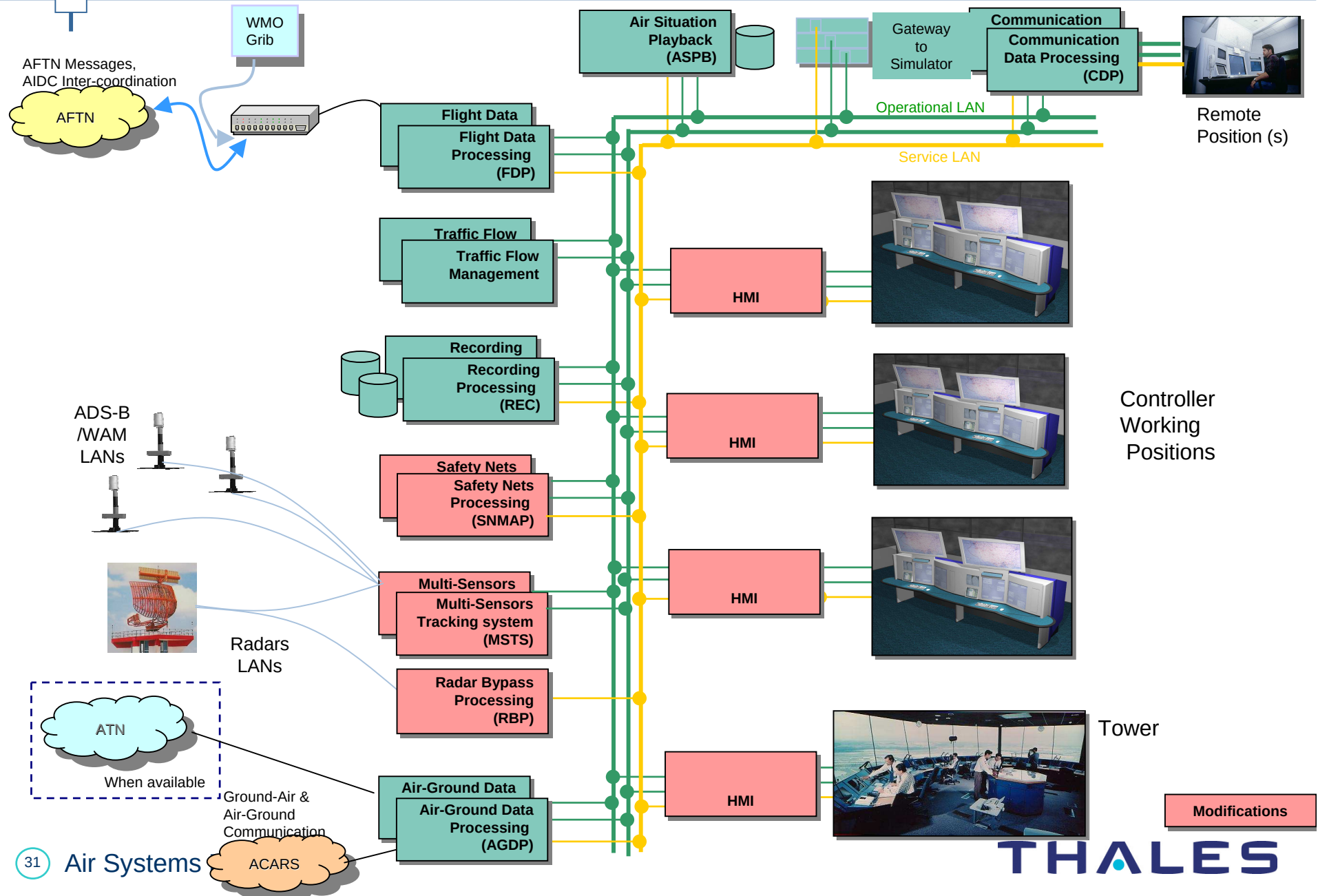
Modifications to ATM Systems

On top of the new surveillance means infrastructure, the ATM system needs modification

Impacted functions includes:

- Surveillance Data Processor
 - Front-End
 - Tracker
- Safety Nets
 - To be adapted to new means
- Controller Working Position (HMI)
 - Symbols
 - New tools (e.g. RAIM Outage for ADS-B)
- Ancillary functions
 - By-pass
 - Recording and replay
 - Simulator

Modifications to a standard ACC Architecture



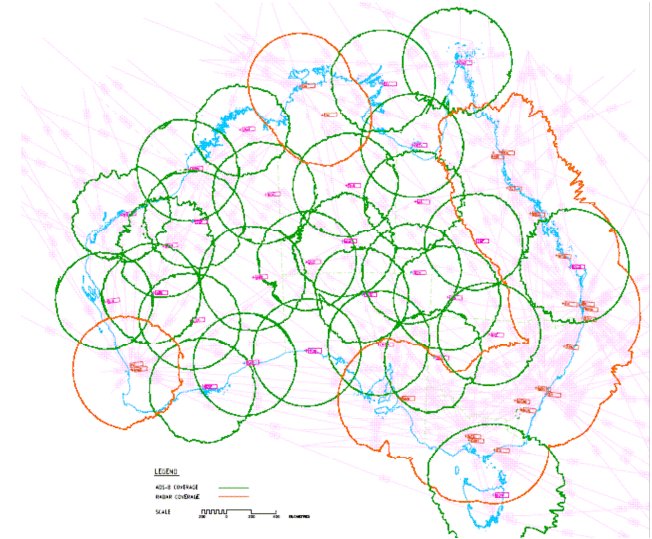


Example : ADS-B in Australia

48 ADS-B sites to feed 2 ACC
2 RCMS sites – one at each ACC location

Existing surveillance

- Radar
- ADS-C

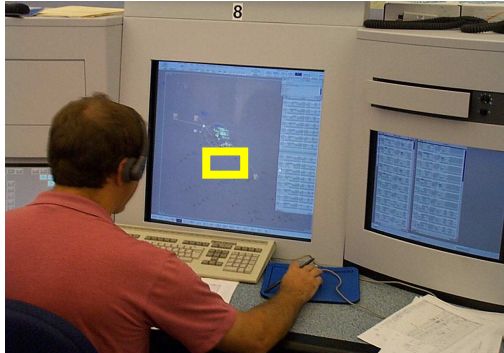


Initial implementation

- Priority scheme: if radar is present then display radar first
- Priority sequence: Radar, ADS-B, ADS-C, Flight Plan

Future implementation

- Fused surveillance data (Radar, ADS-B) using a multi-sensor tracker
- ADS-C remains a separate streams



ADS-B information integration in the ATC control centre (EUROCAT)

- ASTERIX formatted ADS-B tracks
- Tracks coupling to Flight Plan based on Call sign
- Includes Safety Net alerts (STCA, MSAW, etc), conflict detection and conflict handling.
- Integration to recording and analysis tools
- Integration to training simulators

Priority Tracks

Radar Tracks



Dedicated symbol

ADS - B tracks



ADS- C tracks



Flight Plan tracks



ADS-B Integration into TAAATS



**TAAATS ADS-B
and Radar tracks**



TAAATS ADS-B CLAM alert

TAAATS – The Australian Advanced Air Traffic System



Additional hardware and software: ADS-B processing chain

- ADS-B Front Processor
- ADS-B Data Processing
- ADS-B By-pass

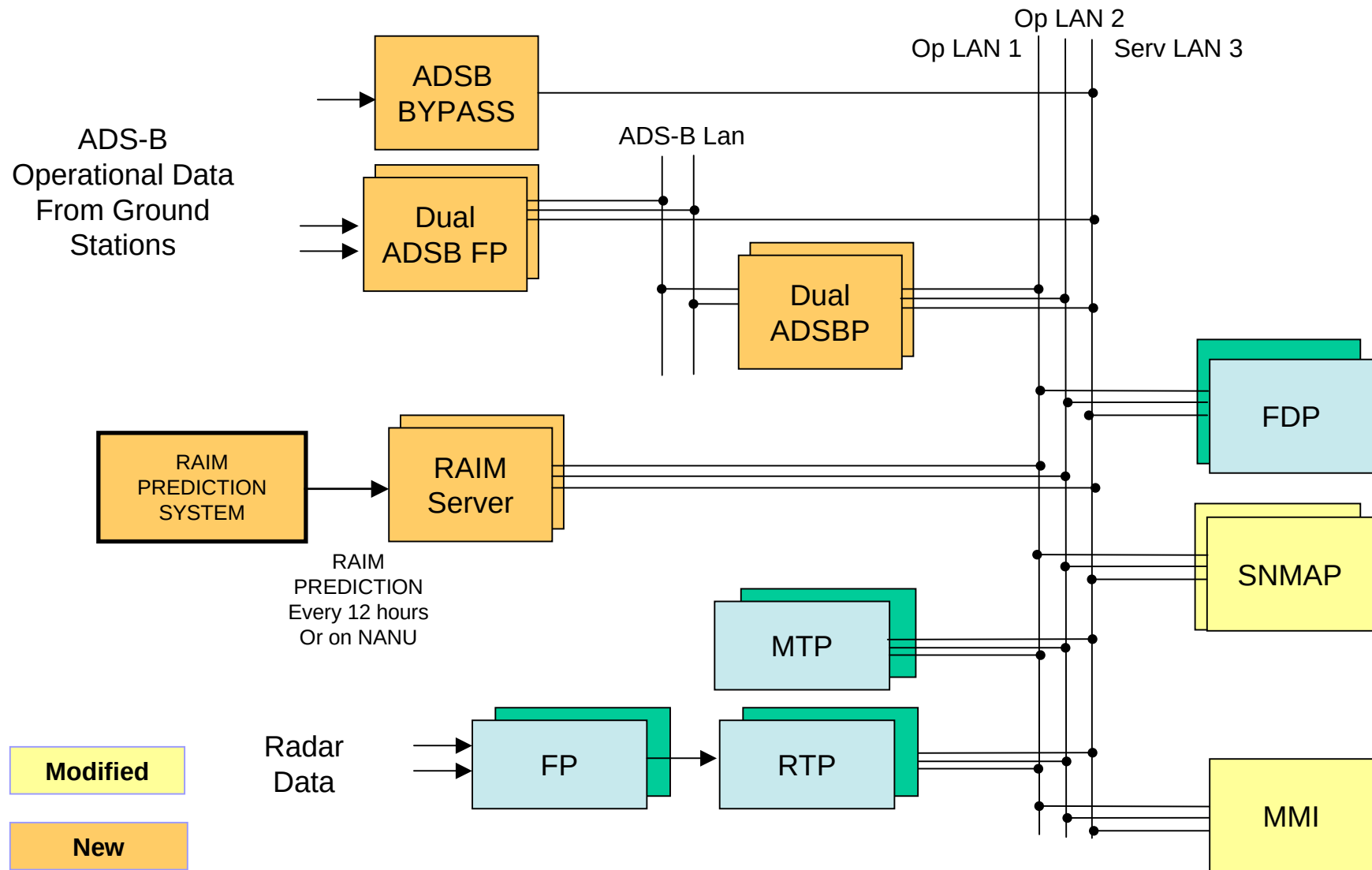
Additional hardware and software: RAIM Outage prediction

- RAIM prediction tool
- RAIM server

Modified software

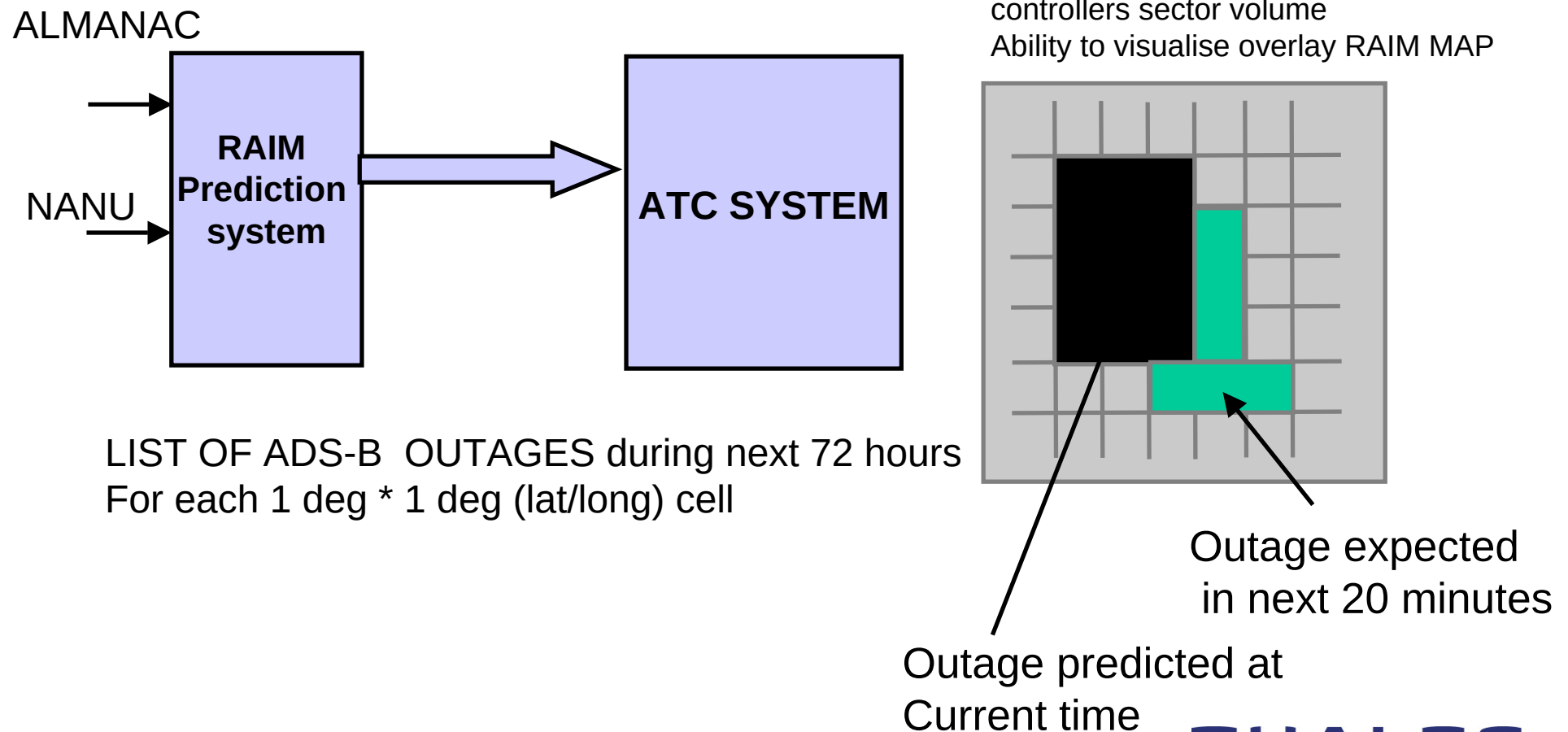
- FDP: tracks coupling
- Safety Net Manager
- Controller Working Position
- Ancillaries

Example of priority Tracks : TAAATS

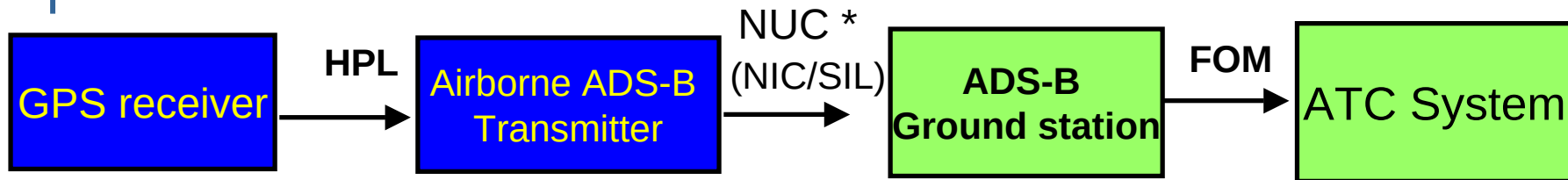


If an outage is predicted in next 20 minutes within a sector :

- Send a warning message to that sector
- Controller has the option to graphically display current and future outage



Quality indicator = Integrity data



HPL: Horizontal Protection Limit
(HIL: Horizontal Integrity Limit)
ARINC Label 130

FOM: Figure of Merit
(PA: Position Accuracy)

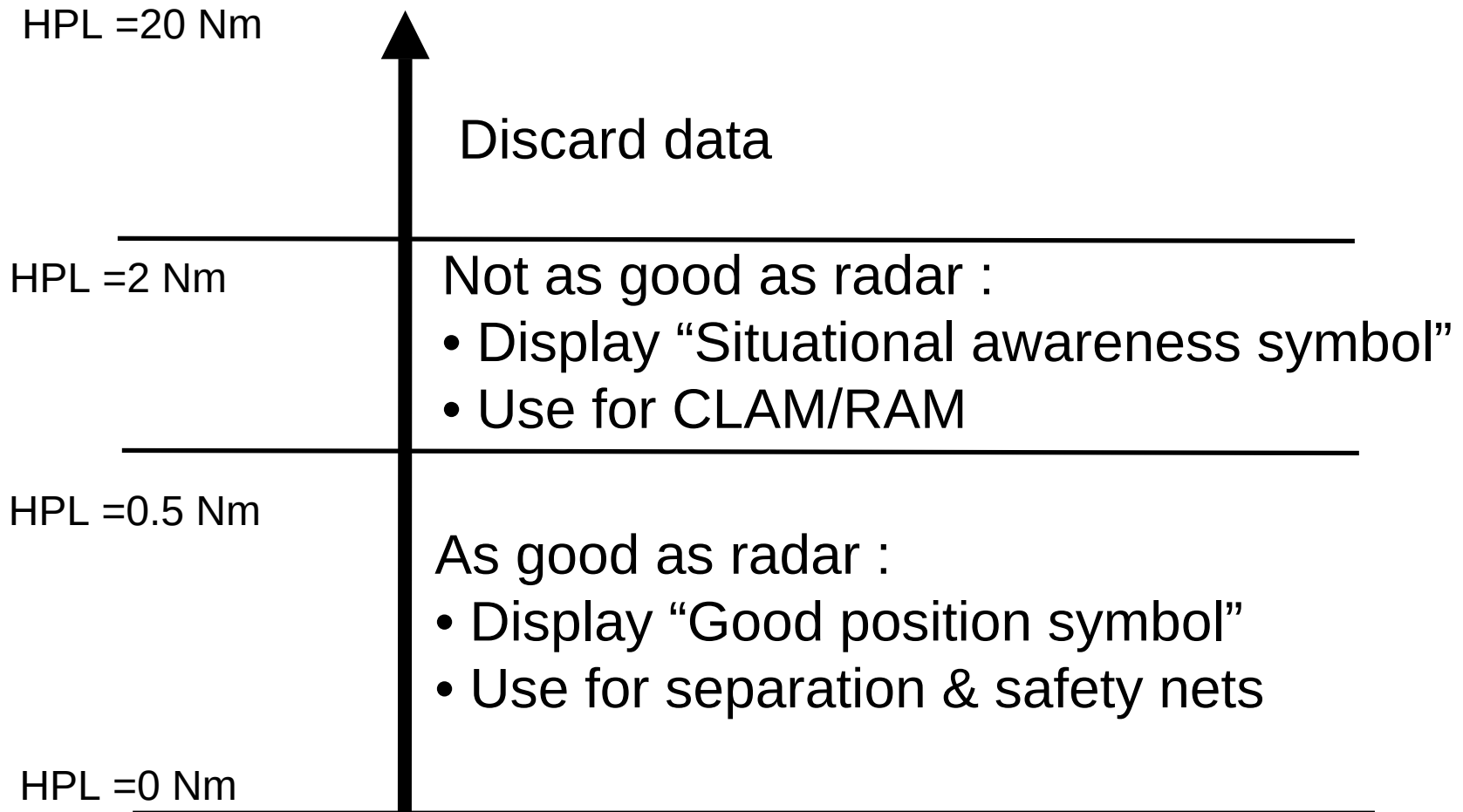
Table 2-11: "TYPE" Subfield Code Definitions (DF = 17 or 18)

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)			Not Applicable	
2	Identification (Category Set C)			Not Applicable	
3	Identification (Category Set B)			Not Applicable	
4	Identification (Category Set A)			Not Applicable	
5	Surface Position	HPL < 7.5 m	μ < 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 $\geq$ 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	μ < 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 $\geq$ 37.04 km (20 NM)	18.52 km (10.0 NM) $\leq \mu$	Baro Altitude	0
19	Airborne Velocity	Not Applicable	Not Applicable	Difference between "Baro Altitude" and "GNSS Height (HAE)"	N/A
20	Airborne Position	HPL < 7.5 m	μ < 3 m and ν < 4 m	GNSS Height (HAE)	9
21	Airborne Position	HPL < 25 m	μ < 10 m and ν < 15 m	GNSS Height (HAE)	8
22	Airborne Position	HPL $\geq$ 25 m	$\mu \geq$ 10 m or $\nu \geq$ 15 m	GNSS Height (HAE)	TBD

What value of
FOM/NUC/HPL is adequate
for radar like surveillance?

Australia to start with
NUC=5

- NUC= Navigational Uncertainty Category
- NUC= Navigational Integrity Category
- SIL= System Integrity Level





Conclusion



New surveillance means are expected to bring significant benefits

- Improved performance (accuracy, alerting)
- Reduced infrastructure costs

However, in addition to the surveillance sensors, other aspects must not be forgotten:

- Regulatory aspects
- Operational aspects (Training, Procedures)
- Adaptation to ATM systems : cannot be just a transformation of data format (eg WAM to radar-like)

THALES products are ready for new surveillance means:

- ADS-B Ground Stations – AS-680
- Multilateration Systems - MAGS
- ATM Systems - EUROCAT



Thank you for your attention

For more information, contact
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