INTERNATIONAL CIVIL AVIATION ORGANIZATION
SOUTH AMERICAN REGIONAL OFFICE

ASSISTANCE FOR THE IMPLEMENTATION OF A REGIONAL ATM SYSTEM TAKING INTO ACCOUNT THE ATM OPERATIONAL CONCEPT AND THE CORRESPONDING CNS TECHNOLOGICAL SUPPORT

SAM IMPLEMENTATION GROUP - SAMIG

GUIDE ON TECHNICAL AND OPERATIONAL CONSIDERATIONS FOR THE IMPLEMENTATION OF ADS-B IN THE SAM REGION

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LIST OF ACRONYMS

A/A	Air/air
AC	Advisory circular
ACAS	Airborne collision avoidance system
ACC	Area control centre
ACID	Aircraft identification
ADLP	Airborne data link processor
ADS-B	Automatic dependent surveillance — broadcast
ADS-C	Automatic dependent surveillance — contract
ADS-R	Automatic dependent surveillance — rebroadcast
AIP	Aeronautical information publication
AIRPROX	Aircraft proximity incidents
ANSP	Air navigation service provider
ASBU	Aviation system block upgrades
ASD	Aircraft situation display
ASTERIX	All-purpose structured Eurocontrol surveillance information exchange
ATC	Air traffic control
ATCO	Air traffic controller
ATM	Air traffic management
ATN	Aeronautical telecommunication network
ATS	Air traffic service
BW	Bandwidth
CAA	Civil Aviation Authority
CDTI	Cockpit display of traffic information
CNS	Communications, navigation and surveillance
CPDLC	Controller-pilot data link communications
DME	Distance measuring equipment
ES	Extended squitter
FDP	Flight data processing
FIR	Flight information region
FMC	Flight management computer
FMS	Flight management system
FPL	Flight plan presented
GNSS	Global navigation satellite system
GPI	Global performance indicator
GPS	Global positioning system
GUI	Graphical user interface
IFR	Instrument flight rules
IMC	Instrument meteorological conditions
INS	Inertial navigation system
ISO	International Organization for Standardization
KVM	Keyboard, video and mouse
LAN	Local area network
MLAT	Multilateration
MSAW	Minimum safe altitude warning system
MSSR	Monopulse SSR
MTBF	Mean time between failures
NTP	Network time protocol
NAC	Navigation accuracy category

NIC	Navigation integrity category
NUC	Navigation uncertainty category
ICAO	International Civil Aviation Organization
PSR	Primary surveillance radar
RAIM	Receiver autonomous integrity monitoring
REDAP	Peruvian digital network
RF	Radio frequency
RNAV	Area navigation
RNP	Required navigation performance
RTCA	Radio Technical Commission for Aeronautics
SAM	ICAO South American Region
SARPs	ICAO standards and recommended practices
SDP	Surveillance data processing
SIC	System identification code
SIL	Surveillance integrity level
SLG	Local management system
SRG	Remote management system
SSR	Secondary surveillance radar
G/A	Ground/air
TCAS	Traffic alert and collision avoidance system
TGPS	All-purpose synchronization card
TIS	Traffic information service
TIS-B	Traffic information service — broadcast
TOA	Time of arrival
TPPG	All-purpose process card
TSO	United States FAA Technical Standard Order
TRPG	All-purpose reception card
TIS-B	Traffic information service — broadcast
UAT	Universal access transceiver
UDP	User datagram protocol
UPS	Uninterruptible power supply
URPA	ADS-B reception and processing unit
UTC	Coordinated universal time
VDL	VHF digital link
VHF	Very high frequency
VFR	Visual flight rules

DEFINITIONS

1. ADS-B (Automatic Dependent Surveillance – Broadcast) – Means by which the aircraft, aerodromes and other objects can transmit and7or receive, automatically, data such as identification, position and additional data, as corresponds, as a data link broadcast.

2. **ADS-B in (reception)**: airborne function that receives surveillance data transmitted by the ADS-B OUT functions installed in other aircraft. It could also receive, from the ground, additional data from other aircraft that do not transmit ADS-B OUT or whose ADS-B OUT systems transmit using a different ADS-B technology.

3. **ADS-B out (transmission): F**unction of an aircraft or vehicle that is periodically broadcasting its status vector (position and speed) and other information obtained from airborne systems in a format suitable for ADS-B-IN receivers.

2. **ADS-R (Rebroadcast):** Function of a ground station that permits the interoperability among aircraft equipped with ADS-B systems that operate with different data links. The ADS-R ground station receives ADS-B messages from a link (*e.g.*, UAT), and processes and broadcasts them through a different data link (*e.g.*, 1 090 MHz ES). Docs 9861 and 9871 contain details of TIS-B and ADS-R.

3. **Downlink**: Link associated to signals transmitted over the 1 090 MHz frequency response channel.

4. **Aircraft identification***:* A group of letters, figures, or a combination thereof, which is either identical to, or the coded equivalent of, the aircraft call sign to be used in air-ground communications, and which is used to identify the aircraft in ground-ground or air traffic services communications (*the aircraft identification is frequently known as flight identification).*

5. **Mode S**: Improved mode SSR that permits selective questions and answers. Mode S that permits selective addressing of aircraft using a 24-bit aircraft address that unequivocally identifies each aircraft and has a bidirectional data link between the ground station and the aircraft for the exchange of information.

6. **Mode S SS (Mode S short squitter):** Periodic unsolicited output of a Mode S transponder (nominally once per second) in a specific format to facilitate passive acquisition.

7. **Mode S ES (Mode S extended squitter):** Periodic unsolicited output in a 112-bit 1 090-MHz Mode S signal format containing 56 bits of additional information (*e.g.*, used for ADS-B, TIS-B and ADS-R).

8. **TIS-B:** Broadcast of aircraft surveillance data by ground stations using an ADS-B data link.

9. **TYPES OF ES MESSAGES:**

10.1 AIRBORNE POSITION: The airborne position message provides basic surveillance information, which includes 3-D position, in addition to time of validity and surveillance status information.

10.2 AIRBORNE VELOCITY: The airborne velocity message contains velocity information and other aircraft status data.

10.3 SURFACE POSITION: The surface position message provides the complete surface status vector in a single message.

10.4 AIRCRAFT IDENTIFICATION AND EMITTER CATEGORY: The identification and category squitter provides the aircraft type category as well as the aircraft identification, which corresponds to box 7 of the ICAO flight plan.

10.5 EVENT-DRIVEN: Event-driven squitter is a message transfer protocol for the transmission of additional information that might be occasionally needed.

10. **Uplink:** Link associated to signals transmitted by the 1 030 MHz frequency interrogation channel.

REFERENCE DOCUMENTS

- Doc 4444, Air Traffic Management (PANS-ATM)
- Doc 9924, Aeronautical Surveillance Manual
- Doc 9871, Technical Provisions for Mode S Services and Extended Squitter RTCA/DO-249, DEVELOPMENT AND IMPLEMENTATION PLANNING GUIDE FOR AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST (ADS-B) APPLICATIONS
- RTCA/DO-242, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance – Broadcast (ADS-B)
- RTCA/DO-260B, Minimum Operational Performance Standards for 1090 MHz extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)RTCA/D0-260 A, Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)
- RTCA/DO260, Minimum Operational Performance Standards for 1090 MHz Automatic Dependent Surveillance – Broadcast (ADS-B)
- Annex 10, Aeronautical Telecommunications, Volumes 4 and v3,
- SAM Surveillance Strategy Document,
- SAM Performance-Based Air Navigation Implementation Plan (SAM PBIP),
- Global Air Navigation Plan for CNS/ATM Systems (Doc 9750), “Aviation System Block Upgrades (ASBU)” Initiative.
- FAA AC No: 20-165 of 2010.
- EASA Acceptable Means of Compliance - AMC 20-24

1. INTRODUCTION

1.1 Objective

1.1.1 Based on the ATM Operational Concept, the Global Plan, the Regional Plan, and the SAM Performance-Based Plan, it is foreseen that the implementation of the ADS-B system will begin in the medium term.

1.1.2 Likewise, following the guidelines of the Global Plan in its GPI 9, “Situational Awareness”, it was determined that one of the activities of Project “Enhancement of ATM situational awareness” would be the development of this guide, which is intended to serve as a reference for SAM States that need to start operating an ADS-B surveillance system. The guide lists the aspects that must be taken into account before deciding to test and then operate the system.

1.2 Scope of the Guide

1.2.1 This guide is addressed to air navigation service providers, civil aviation authorities, and aircraft operators of the ICAO South American (SAM) Region that need introductory information on technical and operational concepts and issues that should be taken into account before planning and implementing ADS-B as an ATS surveillance sensor or as on-board traffic monitoring system to enhance the situational awareness of the crew. This guide does not replace or supplement the international standards specified by ICAO or other standards developers for the industry, but rather provides a common starting point so that SAM States that are planning to acquire an ADS-B or a new control centre may know what are the performance and technical characteristics that will permit the interoperability of the systems involved.

2. OVERVIEW OF THE ADS-B

2.1 OPERATION OF THE ADS-B

2.1.1 According to Doc 9924 AN/474, Aeronautical Surveillance Manual, ADS-B involves the broadcasting by an aircraft of its position (latitude and longitude), altitude, velocity, identification, and other information obtained from on-board systems. All ADS-B position messages contain data quality indication that allows users to determine if data is good enough to support the function foreseen.

2.1.2 Quality indicators of aircraft position, velocity and other related aircraft data are normally obtained from the airborne GNSS system. Existing inertial sensors alone do not provide the required accuracy or integrity data, although future systems will probably solve this deficiency. Consequently, ADS-B position messages from an inertial system are normally transmitted with a statement of unknown accuracy or integrity. Some new aircraft installations use an integrated GNSS and inertial navigation system to provide position, velocity, and quality indicators for ADS-B transmission.

2.1.3 It is foreseen that these navigation systems will have a better performance than a system based only on GNSS, since inertial and GNSS sensors have supplementary features that mitigate the weaknesses of each system. Since ADS-B messages are broadcast, they may be received and processed in any suitable receiver. This receiver may be an “ADS-B ground station” processing ADS-B messages (extended squitter) and generating aircraft reports to be displayed on an ATCO work console.

2.1.4 Figure 1 below illustrates the operation of ADS-B.

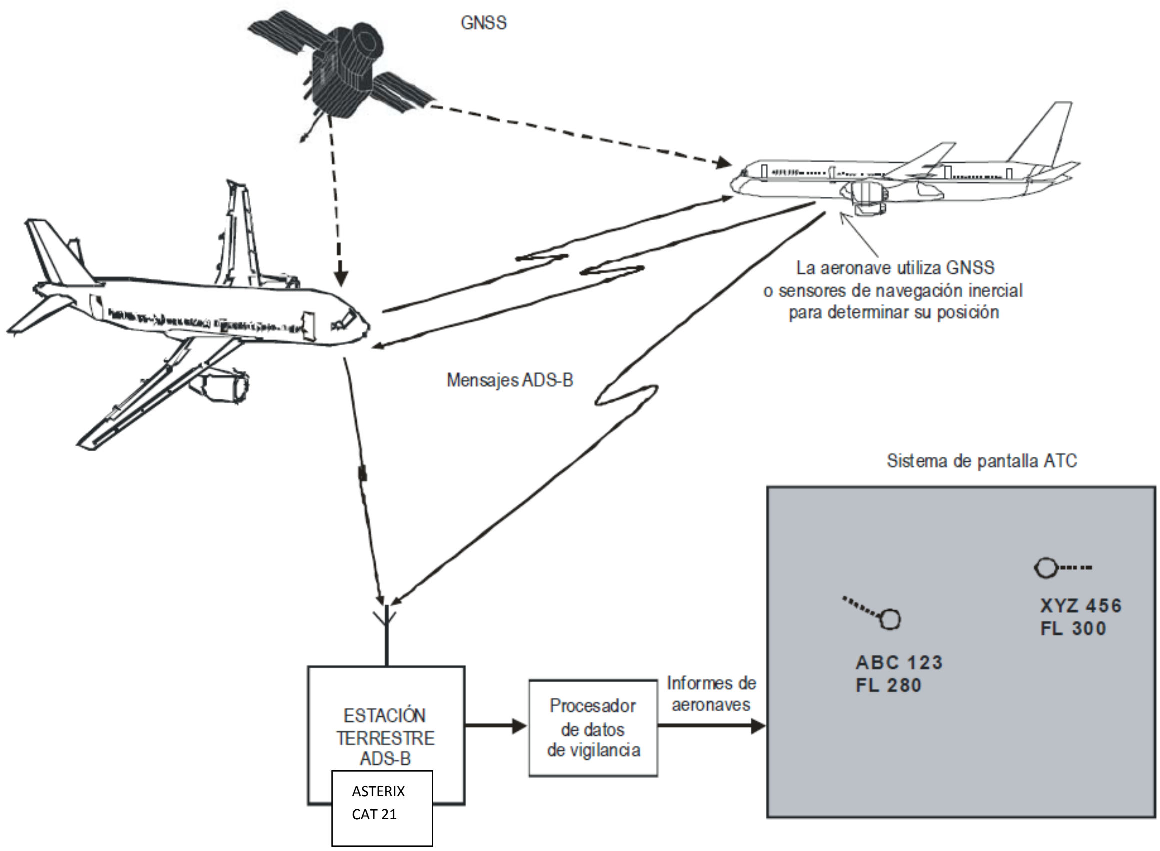


Figure 1: ADS-B schematic

2.1.5 Three ADS-B data links have been developed and standardised for the transport of messages, namely Mode S ES, also known as 1090 ES (Extended Squitter), UAT and VDL Mode 4. Mode S ES has been chosen as the type of link to be used in the SAM Region (GREPECAS Conclusion 12/44 - *Regional CAR/SAM guidance for the introduction of ADS-B data link.* Doc 9871, Technical provisions for Mode S services and extended squitter, provides more details on Mode S ES.

2.1.6 Mode S extended squitter (1090 ES) contains an additional 56-bit data block compared to the conventional Mode S or short squitter (see Figure 2). ADS-B information is broadcast in separate messages, each containing a related data set (*e.g.*, airborne position and pressure altitude, surface position, velocity, aircraft identification and type, emergency information).

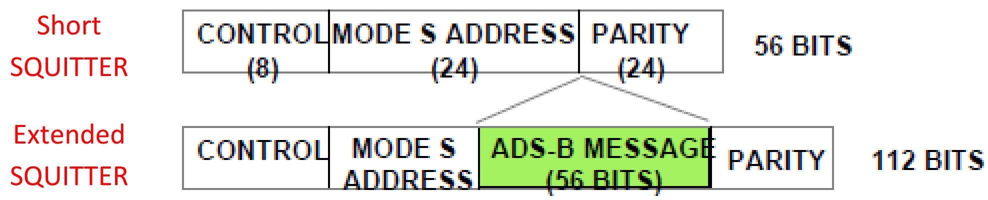


Figure 2. 1 090 ES datagram

2.1.7 The first datagram is the so-called 56-bit Short Squitter (SS), which is transmitted once per second. This short squitter is used for surveillance, where the 24-bit MODE S ADDRESS field embodies the selective interrogation of aircraft addresses consisting of 2 sub-fields, a 9-bit sub-field that identifies the country, and a 15-bit sub-field the identifies the aircraft. Each ES transmission contains the aircraft address, which permits an unequivocal association between the data in the various squitter formats and the originating aircraft.

2.1.8 The second datagram is the 112-bit Extended Squitter (1090 ES) that, in addition to the 56 bits of the SS, contains the 56-bit ADS-B message. There are three standards for the ES: RTCA/DO-260, RTCA/DO-260A and RTCA/DO-260B. these standards correspond, respectively, to Versions 0, 1 and 2, to ICAO Doc 9871.

2.1.8.1 The ES provides five types of reports:

a) Airborne position;
b) Surface position;
c) Aircraft identification and emitter category; and
d) Event-driven.

2.1.8.2 Each of these types is described in Doc 9924 Appendix K item 5 “ADS-B ES messages”. Figures 2A and 2B show examples of ADS-B messages.

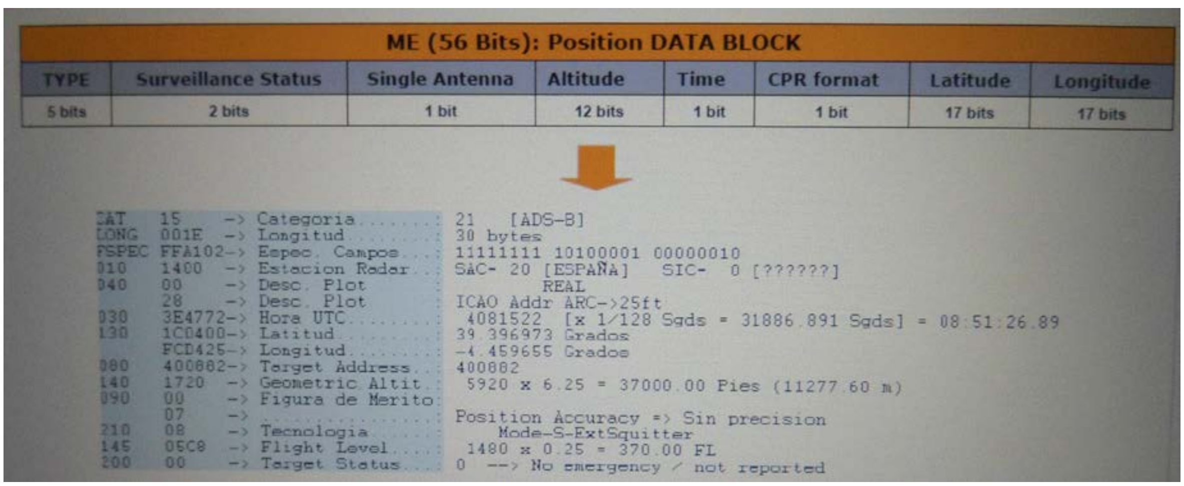


Figure 2A: ADS-B position message

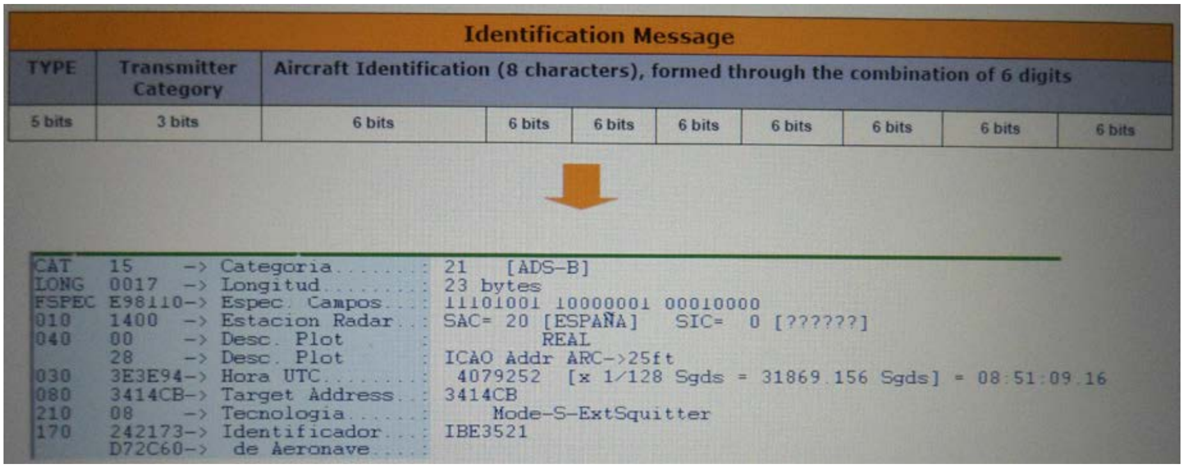


Figure 2B: ADS-B identification message

2.1.9 The initial versions of ES messages are defined in RTCA DO-260 and are known as version ZERO (0) formats. Complete definitions of message structures and data sources for version 0 formats are contained in Doc 9871, Appendix A.
In version 0 formats, the type codes of airborne position and surface position messages can be associated to a navigation uncertainty category (NUC). Version ZERO ES message formats and the associated requirements are suitable for the first implementation stages of extended squitter applications. Surveillance quality is reported in the navigation uncertainty category (NUC), which may be an indication of the accuracy or integrity of the navigation data used for ADS-B. However, it does not specify whether the NUC indicates integrity or accuracy.

2.1.10 The revised versions of ES messages are defined in RTCA DO-260A and RTCA DO-260B known, respectively, as version ONE (1) and versione TWO (2) formats. Complete definitions of the data structure and data sources for versions 1 and 2 formats are contained in Doc 9871, Appendices B and C, respectively. Versions 1 and 2 formats and the associated requirements correspond to more advanced ADS-B applications (see Appendix 1 to this document, “ADS-B operational application”).

2.1.11 In the versions 1 and 2, the accuracy and integrity of navigation data are divided into 3 main components, namely NAC, NIC, and SIL (see Appendix 2 to this document, “Introduction of NAC, NIL, and SIL”).

2.1.12 Each ES transmission contains a 5-bit field that identifies a “TYPE CODE” specific to each message. Version 0 formats allow the TYPE CODES of airborne position and surface position messages to be associated to a NUC. Version 1 formats allow the TYPE CODES of airborne position and surface position messages to be associated to a NIC.

3. GENERAL CONSIDERATIONS ON ADS-B IMPLEMENTATION PLANNING IN THE SAM REGION

3.1 GENERAL CONSIDERATIONS

3.1.1 As stated in Doc 9924, Aeronautical Surveillance Manual, the following list shows the recommended stages for the planning and implementation of surveillance systems--in this case, of an ADS-B system.

a) *Define the operational requirements*:
- Select the applications to be supported: This will help determine the required performance.
- Define the area of coverage: The definition of the volume where the operational service will be supported is very important since it will serve as a basis for system costing. In particular, the correct identification of lower altitude boundaries is very important sincen it will have significant consequences on the number of sensors to be introduced.
- Define the type of traffic: for example, IFR flights, VFR flights, local or international flights, civil or military flights.

b) *Define the local environment (current and future)*:
- Current and expected traffic densities, including a description of likely peak hours.
- Route structure.
- Type of on-board equipment currently mandatory for the different types of flights (mandatory carriage and actual proportion of equipage).
- Type of aircraft: commercial, general aviation, helicopters, gliders, ultra-light aircraft, VLJ, military aircraft, and their dynamic characteristics (maximum speed, climb speed, turn rate, etc.).
- Segregation of the different types of traffic, possible traffic mix, and likelihood of intrusion of aircraft not equipped with means of cooperative surveillance.
- Specific local RF environment.

c) *Analyse design options and determine the techniques that may be used*:
- Verify existing surveillance sensors that may be reused.
- Verify the new sensors and surveillance techniques that may be introduced at a low cost.
- Determine the number of locations and investigate their availability. Check on-board equipment.
- Determine the required level of redundancy and fall back operating mode.
- Determine whether it will be necessary to carry new equipment on board.
- Determine the impact on operating procedures.
- Conduct cost-benefit and feasibility studies of the different options, if necessary.

d) *Conduct a safety analysis of the new proposed system*:
- To demonstrate that the system will provide the necessary performance in its nominal operating mode.
- To demonstrate that the different failures have been analysed.
- To demonstrate that it was determined that failures were acceptable or could be mitigated.

e) *Implement:*
- If new equipment is required on board, prepare the mandate for on-board carriage;
- The acquisition and installation of the new system.
- The performance assessment of the new system.

f) *Establish the operational service:*
- Transition from the existing to the new system.

g) *Provide the operational service*:
- Periodically verify the performance of the new system.
- Perform regular and preventive maintenance.

3.1.1.1 The following proposals provide practical examples of analyses proposed for the Region, taking into account the participants involved.

3.1.2 **Joint work of the CAA and ANSPs**

3.1.2.1 States should consider the following activities prior to the implementation of an ADS-B surveillance service:

a) Define the operational objective of the implementation.

b) Define the objectives and goals to be achieved in accordance with the national air navigation plan, the ASBU surveillance roadmap and the SAM regional surveillance strategy, for the development of the ADS-B implementation plan, with the participation of aircraft operators and other users involved.

c) Services or areas or flight phases that would be under the planning scope.

d) Analysis of the avionics of the fleet, both Mode-S-equipped and non-equipped, in the airspace concerned; at least the following data should be taken into account:

- Number of operations or aircraft involved in general aviation, commercial, and military flights. It is recommended that the ratio between the number of aircraft and the operations they conduct be analysed, since, in some cases, commercial aircraft with 1090ES transmission capabilities conduct several operations per day, thus increasing the feasibility of an implementation with a low final cost for aircraft operators.
- Message standard used for transmission by aircraft (DO-260/DO-260A/DO-260B).

e) ADS-B message standard to be used in the State.

f) Type of application in which ADS-B is to be used in accordance with the requirements and the operational concept (ADS-B-RAD, ADS-B-NRA, ADS-B-APT, ADS-B-ADD, etc.) and the types of transponder that they will require (see Appendix 4).

g) The integration of ES with the SSR system at the existing control centre (if applicable).

h) Advantages, disadvantages, and limitations of the planned implementation.

i) Type of data merging (multi-tracker) of the existing and future SDP serving the ATM automated system.

j) Training of ATCOs and crews on ADS-B, its use, advantages, operational procedures to be used, applicable separation minima, delegation of functions, responsibility limits, etc. Specifically in the case of ATCOs, they shall be warned and trained with respect to the possibility of FLP correlation failures in on-board interfaces due to ACID input errors.

k) Operational risk assessment (in case of failures, navigation data quality degradation, etc.) and ADS-B message performance trials (Doc 4444, 2.6.1.1; 2.6.1.2)

l) Testing and establishment of procedures in case of:

- Contingencies, especially in case of interruption of the receiver autonomous integrity monitoring (RAIM) in accordance with Annex 11, 2.30, and Doc 4444, 8.8.4 and 8.8.5.
- Validation of risk mitigation.
- Independent and joint simulations with pilots.

3.1.3 **Civil aviation authorities (regulatory bodies)**

a) Define the minimum performance and technical/operational characteristics of on-board navigation equipment that will feed ADS-B OUT.

b) Analysis, selection, and validation of quality and integrity parameters in ADS-B message formats in the State.

- Chapters 1, 2, 3 of DO-260A and 2, 3 and 4 of DO242A describe in detail the technical and operational tests and aspects to be taken into account for these processes.

c) Once the testing and parameter selection have been completed, they could be validated as follows:

- The integration of ES with SSR data in a control centre may be a direct way of obtaining ADS-B benefits while maintaining the independence of SSR surveillance. This is based on the use of active interrogation to validate ES surveillance.
- The technique may be used in ground ATC and ACAS surveillance applications. Active surveillance is used for validating the surveillance reported by ADS-B and replacing it if an aircraft loses its navigation capability.
- If the validity check at the beginning of tracking turns out positive, the aircraft may continue in ADS-B with periodic monitoring to ensure the proper continuous operation of the navigation system. If the check turns out negative at any given point in time, tracking can be maintained through active surveillance.

- Another method of validating ADS-B data consists of installing ADS-B with multilateration. The advantage of this option is that it maximises the use of ground infrastructure since multilateration receivers can receive and decode ADS-B messages. This option has the advantage of being completely passive.
- Publication of the respective technical standard as the authority may deem appropriate, highlighting to the ATM community those aspects that crews and aircraft operators (including technical crews on the ground) must take into account when entering data in the on-board interface. (See Appendix 3 – “Proposed publication of a national technical standard.”)
- Drafting of advisory circulars (CA) establishing ADS-B approval requirements for aircraft and operations in the corresponding airspace.

3.1.4 For Operators

a) Equipment with ADS-B message generation and transmission functions. Additionally, for CDTI (Cockpit Display Traffic Information) applications, ADS-B message reception, assembly, and processing functions should be available (in both cases, the data link mode will be ES Mode-S), as well as an appropriate number of interfaces, depending on operational applications, approved by the appropriate ATS authority (see Figure 3).

b) On-board transponders should have the transmission/reception capabilities for the class of transponder (see Appendix 4 “Tables of classes of ADS-B transmitters and receivers”) that corresponds to the ADS-B application to be used, approved by the appropriate ATS authority.

c) The equipment associated to on-board ADS-B may include:

- Secondary sources for navigation data backup and interfaces (for example, redundant GNSS, Loran, FMS / RNAV or INS)
- GNSS augmentation processing
- Interface with applications that support CDTI for visualising other aircraft
- Interface for entering data in the cockpit.

d) Training of crews on ADS-B concepts, the interaction of flight data in ATC applications, the use and procedures of the applications to be used, as well as the contingency plan.

e) Checklists for ADS-B applications to be used, taking into account the importance of correct entry of flight identification in the on-board interface, to be considered for drafting the corresponding technical regulation. Appendix 5, “Aspects to be taken into account by operators when operating an ADS-B transponder”, highlights the importance of this requirement.

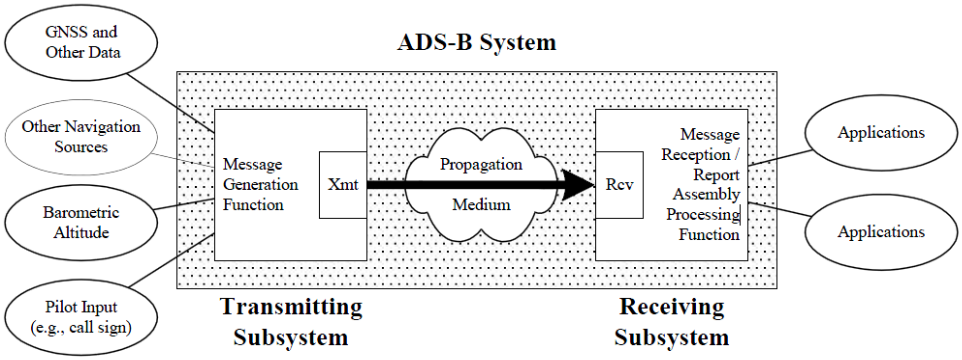


Figure 3: Schematic of ADS-B for operational applications

3.2 ADVANTAGES OF ADS-B

3.2.1 In addition to local, governmental, regional, or global ATM and CNS implementation guides, it is important that the parties responsible for ADS-B implementation planning clearly establish the objectives, advantages, disadvantages, and considerations that this surveillance system entails for the ATM community as a whole, in accordance with it own reality.

3.2.2 In general terms, significant short-, medium-, and long-term safety improvements are achieved (see Appendix 6, "ASBU surveillance methodology roadmap") both on the ground and on board:

a) Enhanced situational awareness in airspaces with radar surveillance or multilateration, through the provision of more information, between IFR, IFR and VFR flights, between VFR flights with electronic VFR IMC function, between uncontrolled flights, to ATC, etc.
b) Enhanced warning (prediction and resolution) systems both in flight as well as on the ground (between aircraft and between aircraft and ground airport operation vehicles), reducing runway incursions, AIRPROX, ATC safety net warnings, long-term warnings for conflict management, etc.
c) Shorter airborne segments.
d) Reduced ATC workload, enabling the delegation of separation responsibilities to certain flights.
e) Different operational applications and functions using a single system
f) Increased airspace capacity, etc.

3.2.3 Regarding economic benefits, savings can be obtained for:

a) ANSPs: lower cost of installing, maintaining and acquiring an ADS-B antenna versus PSR or MSSR, less logistic problems and architecture complexity if compared to multilateration, for example, for broad area; permits the expansion of ATS surveillance service in low traffic density areas where the installation of radar may not be justified, etc.
b) Air users: cost and fuel savings because it enables more direct and optimum routes, less delays and restrictions (with procedures for delegation of responsibilities and tracking, sequencing, and separation functions), etc.

3.2.4 With respect to safety, ADS-B data may be used also for automated monitoring of resolution advisories (RAs) received from collision avoidance systems (TCAS). This functionality may be an additional benefit for States that implement ADS-B coverage in their areas of responsibility, mainly with respect to safety management systems (SMS), since at present RA assessments are normally done using manual processes based on hazard reports sent to the State by the operators.

3.3 DISADVANTAGES OF ADS-B

3.3.1 ADS-B performance and operation standards are still under development. GPS continues to be the main positioning source, still lacking official backup. The additional use of sensors such as DME-DME, INS, etc. as positioning sources is foreseen.

3.3.1.1 The avionics of the fleet that operates in the SAM Region is not homogeneous, and thus some ES-capable flights transmit messages in version 0 and others in version 1.

3.3.1.2 The cost of acquisition of the equipment required for ADS-B is still high, especially for general aviation, which, in many cases, still lacks the necessary FMC/FMS for data processing. The same happens for the ADS-B IN function.

3.3.1.3 Accordingly, it is likely that exclusive airspaces will need to be implemented in the Region.

3.3.1.4 Most control centres lack the capacity to receive ASTERIX category 21ed. 1.8 data or to process and merge data in accordance with the recommendations proposed in this document for the SAM Region.

3.4 SURVEILLANCE STATUS IN THE SAM REGION

The intentions of the States of the Region regarding ADS-B implementation in each country are summarised below, based on CNS plans submitted by each SAM State to the SAMIG.

3.4.1 Argentina

3.4.1.1 Regarding services under the ICAO CNS/ATM concept, Argentina is planning to borrow one or two ADS-B receiver stations to conduct initial trials in this field.

3.4.1.2 Amongst the improvements to be made to surveillance systems for conventional services, Argentina has foreseen the installation in the short and medium term of MSSR radar systems (INKAN from provider INVAP) as conventional services. Plans concerning the new radars are contained in the guide for the implementation of surveillance systems presented at the sixth meeting of the CNS ATM Subgroup (ATM/CNS/SG/6).

3.4.1.3 Regarding services under the ICAO CNS/ATM concept and, specifically, ADS-B plans for the medium term, Argentina contemplates having a sufficient number of ADS-B receivers, which, in addition to the radars foreseen, would ensure the absence of ¨coverage gaps¨. Information obtained from the receivers and from RSMA radars will be carried over the ATN to the corresponding ACCs.

3.4.2 Bolivia

3.4.2.1 Bolivia has an MSSR located in the Kuturipa hill, within the Cochabamba terminal area.

3.4.2.2 Regarding services under the ICAO CNS/ATM concept, Bolivia has no ADS-B stations and its implementation is under study.

3.4.2.3 Amongst the improvements to be introduced in surveillance systems for conventional services and based on an operational requirement, Bolivia has plans to implement an integrated 4-radar (MSSR) system in the medium term to achieve 80% coverage of the La Paz FIR airspace. Regarding services under the ICAO CNS/ATM concept, Bolivia has plans to continue performing cooperative surveillance, noting that SSR Mode A/C and SSR Mode S will continue to be the main surveillance elements for approach, en route and terminal areas.

3.4.3 **Brazil**

3.4.3.1 During the past years, DECEA has promoted radar modernization programmes, in addition to complementing the coverage with the installation of new stations. The result of these initiatives is that the radar network in Brazil is considerably new and the secondary radar coverage is complete for the whole of the Brazilian territory (over FL250).

3.4.3.2 Due to this infrastructure, the criteria for the application of minimum horizontal separations in the Brazilian airspace is in conformity with ICAO dispositions, varying in accordance with the available ATS surveillance, the structure and the complexity of the airspace where this is applied.

3.4.3.3 Surveillance system implementation plans are contained in FASID Table CNS 4A. The plans for the new surveillance systems are contained in the guide for the implementation of surveillance systems submitted to the sixth meeting of the CNS ATM Subgroup (ATM/CNS/SG/6).

3.4.3.4 Regarding improvements to be introduced in surveillance systems, it may be noted that Brazil is contemplating the replacement of radar sensors of conventional surveillance systems for other radars in the short and medium term. Actions foreseen are contained in Annex J to its Plan.

3.4.3.5 Regarding services under the ICAO CNS/ATM concept, ADS-C service was implemented in the Atlantico FIR in 2009.

3.4.3.6 The high precision and updating rate of the information provided by the ADS-B has the potential to increase safety upon applying aircraft separation at the current environments covered by radars, as well as reduce the great separations applied to aircraft at non-radar environments, whoch installation of this type of surveillance is not justifiable under the cost/benefit point of view.

3.4.3.7 In the short term (2013), ADS-B will be introduced for offshore operations at Bacía de Campos. Likewise, a wide area mutilateration (WAM) system will be implemented at the TMA- VT by 2014.

3.4.3.8 In the medium term, ADS-B implementation all over Brazilian continental airspace will be completed in 2018, followed by the elimination of secondary radar coverage overlaps for en-route operations (this requires users to be duly equipped with ADS-B).

3.4.4 **Chile**

3.4.4.1 Regarding the services under the ICAO CNS/ATM concept, Chile has implemented an ADS-C system at the Oceánico control centre, which is used for flight surveillance in areas under its jurisdiction in the South Pacific.

3.4.4.2 Amongst the improvements to be introduced in surveillance systems for conventional services, Chile has plans to renew its equipment, reinforcing the southern area of the country. Regarding services under the ICAO CNS/ATM concept, and with respect to ADS-B, there are plans to study the possibility of implementing an ADS-B system at some airports of the country.

3.4.5 Colombia

3.4.5.1 Regarding services under the ICAO CNS/ATM concept, Colombia has not implemented any ADS-B system.

3.4.5.2 Amongst the improvements to be introduced in surveillance systems for conventional services, Colombia has plans to update its PSR/SSR radar systems and to install a new MSSR radar system at San Andrés in the short term. Regarding services under the ICAO CNS/ATM concept, and with respect to ADS-B, there are plans to expand the MLAT in the medium term to achieve WAM for both terminal area and en route.

3.4.6 Ecuador

3.4.6.1 There are 3 radars located in Guayaquil, Quito and Galápagos. Regarding services under the ICAO CNS/ATM concept, Ecuador has no ADS-B or ADS-C system.

3.4.6.2 Amongst the improvements to be introduced in surveillance systems for conventional services, Ecuador has plans to install PSR and MSSR radar systems in the short and medium term, as well as MLAT. The plans for the new radars are contained in the guide for the implementation of surveillance systems submitted to the sixth meeting of the CNS/ATM Subgroup (ATM/CNS/SG/6). Regarding services under the ICAO CNS/ATM concept, and with respect to ADS-B, Ecuador has no implementation project.

3.4.7 Guyana

3.4.7.1 Guyana has no radar systems. Its CNS Plan specifies that they will “seek the necessary information for radar data sharing”.

3.4.7.2 In addition, Guyana has scheduled the implementation of and ADS-B system in the short term.

3.4.8 Paraguay

3.4.8.1 At national level, Paraguay currently has only one secondary radar Mode S operating in Asunción.

3.4.8.2 Likewise, regarding services under the ICAO CNS/ATM concept, Paraguay foresees that the use of ADS-B in continental area will gradually increase in the air navigation system.

3.4.9 Peru

3.4.9.1 At present, Peru has 7 Mode S radar systems at national level, 1 Mode S radar in Lima, and 1 PSR/MSSR radar system in the city of Lima.

3.4.9.2 In 2009, Peru tested an ADS-B station. In the medium term, (2011-2015), there are plans to conduct tests with the ADS-B system, and the first ADS-B stations based on Mode S ES receivers will be implemented at national level. Currently, an ADS-B system has been implemented in Pisco (210 km south of Lima) but has not been commissioned yet. This system would initially be on trial and then integrated into the Lima ACC.

3.4.9.3 In the long term (2015-2025), the existing Mode S SSR radars will not be renewed and will be replaced at the end of their useful life (around 2020) by ADS-B ES systems.

3.4.10 **Suriname**

3.4.10.1 Suriname has no air surveillance systems. Amongst the improvements to be introduced in surveillance systems for conventional services, Suriname is planning to introduce PSR and SSR soon at the Zanderij/J.A.Pengel international airport.

3.4.10.2 Regarding services under the ICAO CNS/ATM concept, Suriname has no plans for their implementation and, thus, does not foresee the implementation of ADS-B.

3.4.11 **Uruguay**

3.4.11.1 Currently, there are 2 radar locations: Carrasco and Durazno.

3.4.11.2 For the time being, there are no plans to implement ADS-B, only ADS-C for the oceanic sector in the next five years. Regarding services under the ICAO CNS/ATM concept, Uruguay has no ADS-B systems.

3.4.11.3 Amongst the improvements to be introduced in surveillance systems for conventional services, Uruguay has plans to replace the system in Carrasco for a new ASR.

3.4.11.4 Regarding services under the ICAO CNS/ATM concept, Uruguay has no plans to implement ADS-B for the time being, only ADS-C for the oceanic sector in the next five years.

3.4.12 **Venezuela**

3.4.12.1 Venezuela has radars, whose location and characteristics are described in the FASID table.

3.4.12.2 Regarding services under the ICAO CNS/ATM concept, and with respect to ADS-B, Venezuela has foreseen its implementation after 2015.

3.4.13 **Summary of the current status in the SAM Region**

Country	**No. of radars**	**Plans to install ADS-B (*)**	**Defined area**
Argentina	12	YES	Radar coverage gaps.
Bolivia	1	NO	N/A
Brazil	75	YES	Bacia de Campos (oil producing area)
Chile	11	YES	Some airports of the country

Country	No. of radars	Plans to install ADS-B (*)	Defined area
Colombia	15	YES	Multilateration (MLAT) to obtain wide area coverage (WAM) with ADS-B functionality at selected airports.
Ecuador	3	NO	N/A
Guyana	0	NO	N/A
Paraguay	1	YES	N/A
Peru	9	YES	Pisco. Radar coverage gaps.
Country	No. of radars	Plans to install ADS-B (*)	Defined area
Suriname	0	NO	N/A
Uruguay	2	NO	N/A
Venezuela	10	YES	After 2015. Not yet defined.

(*) Information obtained from CNS improvement action plans of the States and provided by the States at the SAM/IG/10 meeting. When the State has not specified its plans to implement ADS-B, it is assumed that it has no plans.

3.4.14 Radar coverage diagrams

3.4.14.1 Appendix 7, "SAM radar coverage diagrams" shows the estimated line of sight of the various radar systems in the SAM Region, at 25,000 feet.

3.4.14.2 To calculate coverage, use was made of software that automatically calculates coverage, using NASA SRTM (Shuttle Radar Topography Mission) data as terrain data, considering a radar tower height of 15 m, and also taking into account the curvature of the earth for a flight level of 25,000 feet. Brazil and Colombia provided their respective coverage diagrams.

3.4.14.3 The diagrams show that the area with the least radar surveillance coverage is located in Bolivia, Paraguay and along their boundaries with Argentina, areas in which implementation could start at regional level.

4. CONSIDERATIONS FOR THE INSTALLATION OF AN ADS-B SYSTEM AND THE TRANSFER OF ITS SIGNAL TO AN AUTOMATED CONTROL CENTRE

4.1 General

4.1.1 Although an ADS-B system can be considered as a technology easy to install, it requires consideration of aspects related to electric facilities, air conditioning, and security, just like any other aeronautical facility, except that its requirements will be minimal.

4.1.2 Consequently, it is important to conduct a site study of the facilities before defining where the ADS-B will be installed.

4.1.2.1 This study must cover:

a) Electric supply
b) Civil infrastructure
c) Environmental conditions. Suitable environment in terms of temperature and humidity
d) Security

e) Assessment of electric power characteristics at the site
f) Connectivity platform
g) Analysis of the site, clearway, and cone of silence
h) Radio electric study of the site to avoid possible interference

4.1.3 If all this were available (installed capacity for integrating ADS-B Indoor and Outdoor to the locations), cost savings would be obtained in terms of UPS, power generator, lightning rod, grounding, castle or mast, security system sensors, the security system itself, etc. Likewise, a connectivity platform with the electric characteristics required to link the physical interface of the ADS-B radar data processor with both the system GUI and the control centre to which it is to be integrated will avoid the need to contract media for only the ADS-B service.

4.1.4 System reliability and availability depends on its quality and structure. Consequently, it is advisable to request dual and/or redundant systems. Redundancy is normally provided at the level of processing channels, data transmission networks, safety, etc.

4.1.5 In the specific case of the Peruvian experience with the ADS-B and installed in Pisco, a series of adaptations have been required. To this end, CORPAC (Peru's ANSP) has made available 2 rooms for ADS-B equipment (one for the sensor and the other for the test equipment).

4.1.6 These premises already had in place all the facilities cited in the previous paragraph, except for the means of transportation and management of the ADS-B radar signal up to the Lima ACC, which is its final destination. To that end, CORPAC personnel used the existing REDAP platform, from which 2 terminals from other services had to be withdrawn in order to have sufficient bandwidth to carry the ADS-B signal from Pisco to Lima. We mention this experience as a reference so as not to neglect any aspect when implementing an ADS-B system.

4.2 Typical equipment in an ADS-B OUT ground station

4.2.1 Typically, an ADS-B system consists of the following equipment, materials, and accessories:

a) Antenna array
b) RF receiving equipment (radio frequency)
c) Surveillance data processor
d) Communications unit (link)
e) Networking units (data communications network)
f) GUI and ACC interface unit (in general, the ATS destination unit)
g) Surveillance data display system
h) ADS-B and processed data maintenance, configuration, and administration management system
i) ADS-B test transponder
j) GPS synchronisation unit
k) RF and electric cabling
l) Trays, ducts, conduits, and accessories
m) Grounding points
n) Lightning arrester
o) Uninterruptible power supply - UPS
p) Electric generating set
q) Security system, involving intrusion, overheating, smoke, and fire sensors; video cameras to record indoor and outdoor environment

r) Air-conditioning system (at least air conditioning, humidity control, and dust filters)

s) Static charge prevention or elimination system or materials. Currently, disposable shoe straps are commonly used in electronic environments subject to static damage.

4.3 Required infrastructure

4.3.1 Typical ground infrastructure

a) Normally, 2 cabinets are required (of a type suited to the physical characteristics of the manufacturer`s equipment) and a castle or mast to install the ADS-B antenna and the lightning arrester system.

Indoors:
Cabinet 1: Contains:
- ADS-B data processor
- Communications unit
- Networking units
- GUI and ACC interface unit (or, in general, the ATS destination unit)

Cabinet 2: Contains:
- Display unit.
- ADS-B and processed data maintenance, configuration, and administration management unit.

Outdoors:
Mast or castle: Contains:
- Antenna
- RF cabling
- Lightning rod, on top of the castle or mast
- Lightning rod power lines

b) The location, at a distance previously determined by the provider of the installation in such a way as to avoid losses from excessive cabling, shall have:

- Lightning rod grounding with resistance values not to exceed 30 ohms
- ADS –B system grounding with resistance values not to exceed 5 ohms

c) Aerial trays are recommended for placing the data cables to connect indoor equipment and to connect indoor to outdoor equipment. Data and electric cabling trays must be different in order to avoid electromagnetic interference that will affect data cabling and thus the ADS-B system.

d) Environmental considerations: Cleaning. Dust is extremely detrimental for the proper operation of equipment; consequently, normal cleaning and general maintenance of the room are essential to avoid problems, especially in connectors and disc units.

e) Interference and disturbances: Different sources may generate interference and/or disturbances. To solve that, there are some products that may be considered.

- Electric discharges: Rugs and low humidity are two main static generators. The equipment should not be installed in rooms with rugs or similar materials, and the humidity range in the room must be controlled. Low humidity is equivalent to static, thus the importance of maintaining humidity within certain ranges. Accordingly, consideration must be given to installing antistatic floors suitable for technical rooms.
- Electromagnetic radiation: Data and electric power cables must run on different trays, maintaining the necessary separation to avoid radiation and interference (needless to say, in case of interference, the data cabling will be the most affected).
- Site assessment: The area to be selected must be as free as possible of obstacles or it must be assured that the terrain model will not be modified in a way that will affect the line of sight of the ADS-B receiver with respect to the air fleet to be served. Likewise, the cone of silence concept must be kept in mind. It is better to foresee a value for the cone of silence than not have any, since, under actual operating conditions, there will be a coverage blind area. Accordingly, a theoretical value between 30 and 90 degrees may be assumed to avoid subsequent surprises.
- Interference to/from other stations: In the ATC environment, SSR, ADS-B, ACAS and military IFF systems use the same frequencies (1 030 MHz and 1 090 MHz) (see Figure 4). Technical and operational changes in one of the aforementioned systems has consequences on the system itself, on the system involved, on other systems operating on the same frequencies, and even on systems that operate on neighbouring frequencies (*e.g.,* DME). The following figure shows 1 030/1 090 MHz systems as part of the 960 MHz–1 215 MHz aeronautical frequency band. Interference may lead to degradation of system performance, with loss of information or erroneous information. Thus, when selecting the site to install ADS-B antennae, consideration must be given to physical and frequency proximity to other navigation systems at the airport, especially DME systems and surveillance radars.

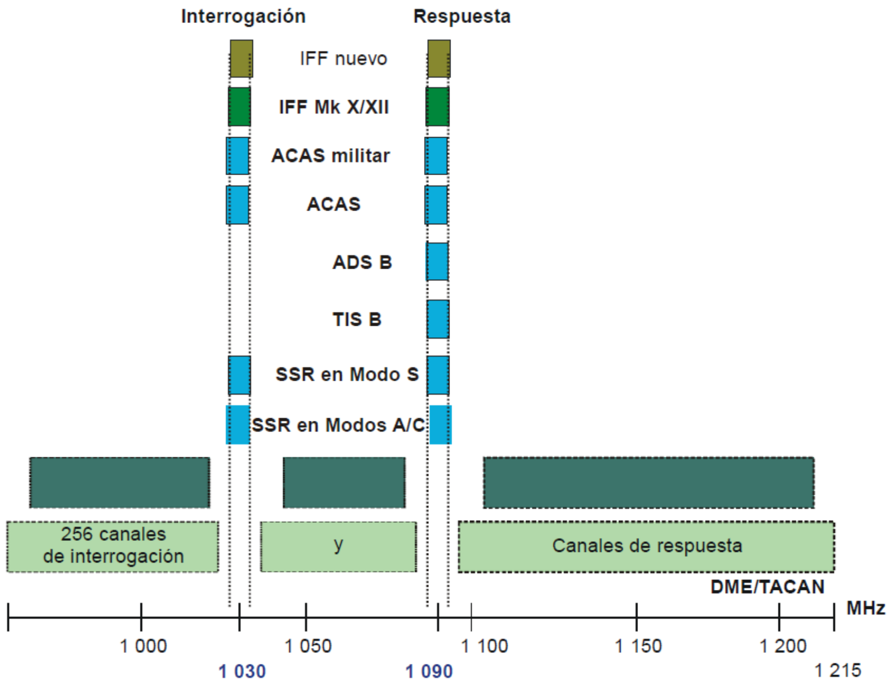


Figure 4. Channels and frequencies in the 960 MHz – 1 215 MHz aeronautical frequency band

f) Temperature: System operation will be more reliable if temperature is kept within a stable range (more conservative than that specified in the manufacturer's manual), the recommendation being between 20º and 25º C. High and unstable work temperatures increase the frequency of circuit failure. However, systems can work for short periods of time at higher or lower temperatures, and it is recommended that ADS-B equipment suppliers be requested to provide the values of the following parameters:

- Operating temperature:
- Minimum temperature:
- Maximum temperature:
- Temperature variations: expressed in T°/ time (° C / hour)
- Instantaneous variations: expressed in T°/ time (° C / minute).

g) Humidity**:** It is recommended that the relative humidity in the rooms selected for the installation be kept between 40% and 60%, with no condensation. Low humidity levels can produce static electricity, while high humidity levels can cause problems in paper feed to printers, as well as fungi problems in magnetic tapes and discs.

The following humidity specifications are recommended:

- Relative air humidity: 40 - 60%, with no condensation.
- Maximum relative humidity: 80%.
- Minimum relative humidity: 30%.

h) Air conditioning: The air conditioning system shall maintain the temperature and humidity of the room within the indicated specifications.

4.3.2 **Installation design structure**

a) Identification of rooms and sites

Order is important in any facility, even more so in critical systems such as those related to the aeronautical service. Therefore, the establishment of an identification system is the most relevant activity towards the attainment of such order. This will facilitate the task of maintaining and assessing the behaviour of this type of system. It is recommended that system positions be numbered for purposes of identification, giving each system component an identifier, with different prefixes to indicate location, floor, environment, rack, rack level, and the corresponding numbering. Similarly, structured cabling recommendations must be unrestricted. The system supplier must be requested to provide general diagrams of ADS-B connections under the established identification system, as well as of ADS-B LAN cable connections, antennae-rack connections, and connections to the GPS, NTP servers and remote clocks.

b) Identification cabling

- A checklist must be produced with information on point-to-point cable connections.
- Each rack must have a physical list of the cables associated to that rack.
- Likewise, cable labels must contain all the information associated to the rack.
- Each cable contained in the list is identified by a reference number, which is linked to a list of cable suppliers, with manufacturing details concerning signal/names/functions.
- Each label must precisely indicate the beginning and the end of the cable, as well as where should it be connected within the cabling array.

The types of cables normally installed are:

- Radar cabling between the antennae and the filters, between the filters and radar data processors, between processors and the KVM (keyboard, video and mouse), between GPS antennae and processors. To this end, coaxial cables, such as RG-58, RG-214, RG-179, are normally used. Cable gauges will depend on the distance and the technical details of each manufacturer.
- For indoor cables that connect processors to information output interfaces for radar or data display or management, RJ45 Cat 5E is used as a minimum. It would be even better if a superior category of structured cable is used in accordance with standard T568B.

c) Required capacity of the national aeronautical network

- The means of transportation of the signal must take into account the protocols and formats of the radar data provided by the ADS-B.

- Due to the nature of the service, ADS-B data must have an IP medium compatible with the Multicast UDP-type transport level protocol. This usually complicates the link between the ADS-B sensor and the ACC, since public service providers normally use the TCP transport layer protocol for their networks and for providing IP services.
- CORPAC has a frame relay network that has been used to link the ADS-B from Pisco to Lima.

4.4 Receiver autonomous integrity monitoring (RAIM)

4.4.1 It is expected that the first ADS-B implementations will use GNSS for positioning. In this regard, since the availability of GNSS data has a direct impact on the provision of surveillance services, ATS service providers can choose to use a GNSS integrity prediction service to help determine the future availability of usable ADS-B data.

4.4.2 The service integrity prediction alerts users to a possible future loss or degradation of the ADS-B service in defined areas. With these alerts, the system is warning users that at some point in the future, ADS-B position data may be insufficient to support the ADS-B separation application.

4.4.3 It is advisable that the prediction service be made available to each ATS unit that uses ADS-B for the provision of separation services, to make sure that air controllers are warned before any foreseen degradation of the GNSS service and the resulting reduced ability to provide flight separation ADS-B within the affected area. This is similar to having advanced warning of a planned interruption of the radar system due to maintenance.

4.4.4 ADS-B must not be used to provide separation between aircraft during the period in which it is expected that the integrity of position reports will not be adequate.

4.4.5 If an unexpected loss of integrity occurs (including a crew RAIM alert report), then:

a) ADS-B separation must not be used by ATC for aircraft until integrity is assured, and

b) The controller must check if other nearby aircraft have filed RAIM alert reports to see if they have been affected and to establish alternative means of separation if necessary.

4.4.6 More information about RAIM can be found in Appendix 8 to this document.

4.5 Operational tests

4.5.1 Once the ADS-B system has been installed, a cabling installation certificate must be requested from the manufacturer or responsible company.

4.5.2 The ADS-B transponder testing system will permit the necessary target adjustment in order to achieve optimum signal integrity. This system is referential.

4.5.3 Regarding operational tests, these must start with a physical level link tests and, if successful, continue with UDP multicast traffic transmission tests from the sensor location to the ATS destination unit. For Peru, the test was conduct from Pisco to Lima (REDAP room node-Lima).

4.5.4 If successful, the next tests are to check if the data received is compatible with the application of the air traffic management system provider, which must be capable of processing data in the ASTERIX CAT 21 ed 1.8 protocol.

4.5.5 Regarding the bandwidth of the means of transportation for Lima, the peak is 18 kbps, but this will depend on the number of aircraft with ADS-B avionics that circulate through the airspace to be controlled. The recommended bandwidth for the means of transportation is no less than 64 Kbps.

4.5.6 Flight check tests are an integral part of ground-based ADS-B system testing. The aircraft to be contracted must be properly equipped with 1090 MHz Extended Squitter (1090ES) transponders and recording equipment. Flight routes must be established to test both uplink and downlink services within the defined airspace. More information on flight check testing can be found in Appendix P to Doc 9924 - *Aeronautical Surveillance Manual*.

4.5.7 The information required for assessing the ADS-B system through flight tests must include performance parameters, including minimum ADS-B information update interval, volume of coverage over the geographical area where the ADS-B service is to be provided, radar data accuracy, identification data, maximum data latency, and data validation functions.

4.5.8 An important aspect that must be tested is ADS-B interoperability in the surveillance setting of each State, to ensure that ADS_B will not degrade systems already operating in 1090 MHz. This interoperability with other systems in RF frequencies must be one of the objectives of operational tests.

4.5.9 The flight test methodology can be found in WP ASP12-05-Doc-9924 “Change Proposal for Guidance Material on Flight Testing of New Surveillance Systems”.

4.5.10 Another important aspect is the sharing of the means of transportation. Although service integration is what is recommended today, it is important to note that the means should prioritise services. That is, if it is decided that the means of transportation carrying the ADS-B signal will also carry essential services like G/G or G/A speech communications, bandwidth segmentation or assignment techniques should be used to prevent surveillance data information from interfering with speech communications, causing mini voice interruptions (on-line service that admits no delays).

4.6 Training of technical personnel

4.6.1 The technical personnel at the sensor site and at the management site of the network that carries the ADS-B signal must be involved in the installation and testing from the beginning. Likewise, they must receive training on the structure of the system, operating characteristics and conditions, radar signal flow, and every technical detail that allows the system to operate under the foreseen nominal conditions.

4.6.2 At the network management site, the bandwidth used for the ADS-B system multicast traffic must be monitored, and the respective changes of processing channels must be coordinated, if applicable, with the resident technician in case remote management or other type of activity is not available.

4.6.3 A final recommendation is that personnel in charge must at all times remember that if the ranges and data specified by the system manufacturer are disregarded, the useful life of the equipment will be degraded and, consequently, reliability will be lost.

4.6.4 The ADS-B system model presented below (Figure 5) may serve as a reference.

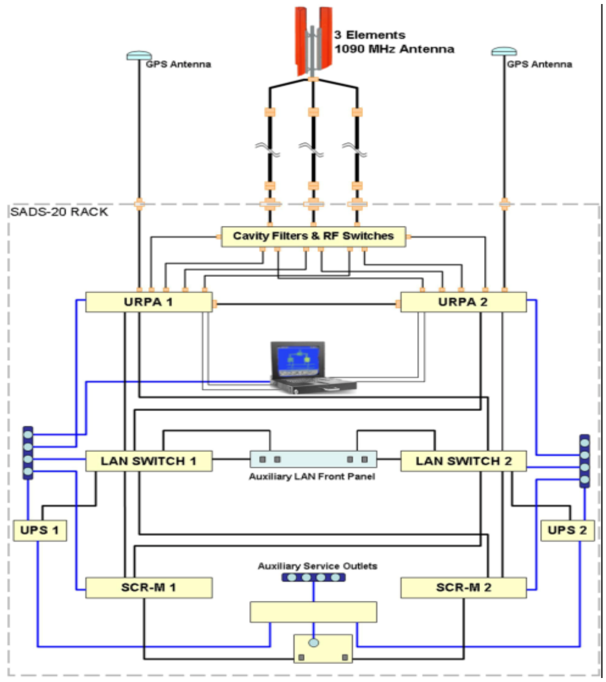


Figure 5: ADS-B Architecture Model

<u>The arquitecture is composed by the following elements:</u>

- Antenna set:
  - Three independent sectors

- Distribution of RF signals:
  - Set of radio frequency filters and relays

- ADS-B processing receiver unit (APRU):
  - 3 1090-MHz receiver cards
  - 3 processing cards
  - 1 GPS synchronisation card
  - 1 software card (Linux OS)

- Local management system (local control and monitoring))
  - Based on the Unix system
  - System capable of integration with the APRU or any other equipment.

- Communication system:
  - Two (2) redundant LAN networks
  - Routers

5. FUNCTIONAL RECOMMENDATIONS FOR AUTOMATED AIR TRAFFIC MANAGEMENT SYSTEMS TO BE USED WITH ADS-B IN THE SAM REGION

5.1 In order to achieve a common interoperability standard for the use of ADS-B in the SAM Region, in addition to that provided for in Chapter 8.2 of Doc 4444, automated air traffic management systems used by ANSPs should have at least the following technical and operational characteristics:

a) If navigation information is degraded according to the appropriate State ATS authority, the control centre should be able to determine when the reported accuracy and integrity values are sufficient to support a given application (*e.g.*, control with ATC surveillance for 5NM separation). Consequently, it should be capable of entering the allowable information quality and integration (NUC, NIC/NAC/SIL) threshold values that correspond to the ADS-B message version. States should be able to configure these parameters without the intervention of the provider.

Note: Reference: Doc 4444 Chapter 8.1.10 and, for more details about these concepts and ES performance, see document DO-260A Chapters 2, 3 and 4.

b) Appropriate visual alarm display at the ASD in case of deterioration of the minimum value(s) entered as per paragraph a) above, so that ATS units may distinguish between a radar blip, a multilateration blip, and an ADS-B blip (or a combination of these) beyond the limits established for providing separation in the airspace concerned (ref. Doc 4444 Chapter 8.2.5).

c) For the purpose of analysis and study by the States, it is recommended that automated systems maintain ADS-B plot generation capability, even beyond the established limits mentioned in paragraph “a” above, for non-operational display (technical monitoring). However, these out-of-limit plots should not be taken into account by the multi-tracker for merging with data from other sensors.

d) Information displayed on the ASD about the type of surveillance sensor used (whether one or several sensors), so as to identify each combination.

e) Performance of the information on the corresponding parameters received in ADS-B messages (ADS-B-ADD) concerning the safety nets processed by the surveillance system SDP or FDP, as appropriate (see Appendix 1, “ADS-B operational applications”).

f) Processing of ASTERIX Category 21 edition 1.8 messages (Appendix 9 “Asterix Category 21 Ed. 1.8”)

g) Capability of processing “version 0” and “version 1” ADS-B messages simultaneously (ICAO Annex 10, Volume 4, item 5.2.4).

APPENDIX 1 - ADS-B OPERATIONAL APPLICATIONS

In general terms, in order to take advantage of the amount and types of data provided by ADS-B, the following are considered as possible operational applications:

1. CDTI (Cockpit Display of Traffic Information)
2. Airborne collision avoidance
    a. Enhancements to existing airborne collision avoidance systems
    b. ACAS based on ADS-B
3. Conflict management and airspace conflict resolution
    a. Airborne conflict management and airspace conflict resolution
    b. ATS surveillance and conflict management
4. ATS conformity monitoring
    a. Successive approaches
    b. Incursion processes (special use airspace, restricted airspace, bad weather area hazardous for flights, runways and taxiways, controlled lighting area (under ATS control), areas with weight and wing span limitations, and other operational control areas, such as noise-sensitive areas.
5. Enhanced search and rescue
6. Enhanced tracking between flights
7. Light operations and control
8. Operational requirements of airport ground vehicles and aircraft rescue and fire fighting vehicles (ARFF)
9. Performance measurements for maintaining altitude/height
10. Control of general aviation operations

    Note: For more details about these recommended applications and requirements, see Appendix D and E to document DO-242A.

The SAM surveillance strategy includes the implementation of ADS-B Package I, consisting of a set of ground-based surveillance applications, improved situational awareness of traffic, and on-board delegation of spacing.

ADS-B Package I ground surveillance applications seek to improve ATC surveillance en route, in the TMA, and on the airport surface, and to improve ATC tools through the provision of aircraft-derived data *via* ADS-B. These applications are:

- ADS-B-RAD ATC surveillance of TMA and en-route airspace in areas already covered by radar systems
- ADS-B-NRA ATC surveillance of non radar areas
- ADS-B-APT surveillance of the airport surface
- ADS-B-ADD data derived from the aircraft for ATC tools

ADS-B Package I on-board surveillance applications seek to improve on-board surveillance (cockpit) of en-route and TMA airspace and airport surface.

These applications are:

- ATSA-SURF Improved situational awareness of traffic on the airport surface
- ATSA-VSA Improved visual separation during approach
- ATSA-ITP Wake procedure in oceanic airspace
- ATSA-AIRB Improved situational awareness of traffic during flight operations

Note: States that will implement these functions should take into account Chapter 5 of Annex 10 v4, as well as DO-260A, Chapter 2.1.11 and 2.1.12 (for quick reference, Annex A with the tables of these 2 chapters is attached to this document)

ADS-B Package I on-board spacing applications seek to use on-board surveillance capabilities (cockpit) to run applications whereby the crew can maintain a given time and distance from designated aircraft. These applications are:

- ASPA-S&M Improved sequencing and merging operations
- ASPA-C&P Improved crossing and passing operations

APPENDIX 2 – INTRODUCTION OF NAC, NIL, SIL

2.2.1 Surveillance accuracy and integrity are reported separately as navigation accuracy category (NAC), navigation integrity category (NIC) and surveillance integrity level (SIL).

2.2.2 ES version 1 formats also include provisions on improved status information reporting. Amongst other aircraft parameters, the operational status message contains the version number of the ADS-B transmitter equipment, the SIL parameter, and the navigation accuracy category for position (NAC_P).

2.2.3 Version 1 formats allow type codes of flight position messages and surface position messages to be associated with a NIC.

2.2.4 The NIC is reported in such a way that surveillance applications can determine if the reported geometric position has an acceptable level of integrity for the use foreseen. The NIC parameter specifies an integrity containment radius (Rc). In this regard, document DO242A describes the close relationship between the NIC value and the SIL and the Rc.

2.2.5 The SIL parameter acts together with the NIC parameter, and specifies the probability of the actual position being outside of the containment radius without any alerts being activated.

2.2.6 The NAC_P parameter is reported in such a way that surveillance applications can determine if the reported geometric position has an acceptable level of accuracy for the use foreseen.

2.2.7 Document DO-242A, amongst other notes contained in table 2-3, specifies that:

2.2.7.1 The EPU – (Estimated Position Uncertainty) corresponds to a 95% accuracy bound on horizontal position. The EPU is defined as the radius of a circle, centred on the reported position, such that the probability of the actual position being outside the circle is 0,05. When reported by a GPS or GNSS system, the EPU is commonly called HFOM (horizontal figure of merit).

2.2.7.2 The NIC and NAC_p currently used in DO242A replaced the NUC_p of the previous version of the MASPS.

2.2.7.3 RNP accuracy includes other sources of error aside from the sensor, while the horizontal error for NAC_P only refers to the certainty of the horizontal position error.

Table 2-3: Navigation Accuracy Categories for Position (NAC_P).

NAC_P	95% Horizontal and Vertical Accuracy Bounds (EPU and VEPU)	Comment	Notes
0	EPU ≥ 18.52 km (10 NM)	Unknown accuracy	
1	EPU < 18.52 km (10 NM)	RNP-10 accuracy	1
2	EPU < 7.408 km (4 NM)	RNP-4 accuracy	1
3	EPU < 3.704 km (2 NM)	RNP-2 accuracy	1
4	EPU < 1852 m (1NM)	RNP-1 accuracy	1
5	EPU < 926 m (0.5 NM)	RNP-0.5 accuracy	1
6	EPU < 555.6 m (0.3 NM)	RNP-0.3 accuracy	1
7	EPU < 185.2 m (0.1 NM)	RNP-0.1 accuracy	1
8	EPU < 92.6 m (0.05 NM)	e.g., GPS (with SA)	1
9	EPU < 30 m and VEPU < 45 m	e.g., GPS (SA off)	2
10	EPU < 10 m and VEPU < 15 m	e.g., WAAS	2
11	EPU < 3 m and VEPU < 4 m	e.g., LAAS	2

2.2.8 SIL information will be even more important when the position of the aircraft is determined by an on-board system that combines GNSS and INS and other navigation sources, such as DME-DME, to which end the aircraft should transmit the highest SIL that position sensors can support, so that it can be used in more demanding applications.

Note: DO-242A elaborates on this point with a note on SIL and the following table: *"It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used. Thus, for example, if an ADS-B participant reports a NIC code of 0 because four or fewer satellites are available for a GPS fix, there would be no need to change the SIL code until a different navigation source were selected for the positions being reported in the SV report."*

SIL	Probability of Exceeding the R_C Integrity Containment Radius Without Detection	Comment
0	Unknown	"No Hazard Level" Navigation Source
1	1×10^{-3} per flight hour or per operation	"Minor Hazard Level" Navigation Source
2	1×10^{-5} per flight hour or per operation	"Major Hazard Level" Navigation Source
3	1×10^{-7} per flight hour or per operation	"Severe Major Hazard Level" Navigation Source

Note: It is important that, for final implementation reference, States use the values in this table, together with the appropriate NAC and NIC values, as specified in the MASPS, MOPS and Annex 10.

2.2.9 If a State is planning to use the TIS-B (Traffic Information System - Broadcast) based on SSR/MSSR for relaying information, the SIL could change depending on different considerations, such as the individual characteristics of the sensors used, whether the targets are captured by one sensor or a combination of sensors, coverage, the multi-track system used, etc. (see Chapter 5 of Annex 10 v.4, Appendix 1 to this document, and DO-260A)

2.2.10 States shall take into account that DO-260A, in Chapter 2.2.3.2.7.2.6, specifies that the NIC reported in "status reports" or SV is not explicitly transmitted in the ADS-B message, since it is 1 bit of the sub-field ("ME" bit 44, Message bit 76), but rather must be determined from "TYPE CODES". The NIC supplement could be used to distinguish between 2 very close Rc values. Table 2-70 of that same document, shown below, lists NIC code types.

Table 2-70: Navigation Integrity Category (NIC) Encoding.

NIC Value	Containment Radius (R_C) and Vertical Protection Limit (VPL)	Airborne		Surface	
		Airborne Position TYPE Code	NIC Supplement Code	Surface Position TYPE Code	NIC Supplement Code
0	R_C unknown	0, 18 or 22	0	0, 8	0
1	R_C < 20 NM (37.04 km)	17	0	N/A	N/A
2	R_C < 8 NM (14.816 km)	16	0	N/A	N/A
3	R_C < 4 NM (7.408 km)	16	1	N/A	N/A
4	R_C < 2 NM (3.704 km)	15	0	N/A	N/A
5	R_C < 1 NM (1852 m)	14	0	N/A	N/A
6	R_C < 0.6 NM (1111.2 m)	13	1	N/A	N/A
	R_C < 0.5 NM (926 m)	13	0		
7	R_C < 0.2 NM (370.4 m)	12	0	N/A	N/A
8	R_C < 0.1 NM (185.2 m)	11	0	7	0
9	R_C < 75m *and* VPL < 112 m	11	1	7	1
10	R_C < 25m *and* VPL < 37.5 m	10 or 21	0	6	0
11	R_C < 7.5m *and* VPL < 11 m	9 or 20	0	5	0

Note: *"N/A" means "This NIC value is not available in the ADS-B Surface Position Message formats."*

2.2.11 Following the analysis that States must conduct of the NIC, NAC, SIL, it is expected that official values will be published in accordance with the ADS-B applications being considered. The following table shows an example of these values, which by no means should be considered as the actual values.

Application	NAC	NIC	SIL
ATC service with 5NM separation	6	8	2
ATC service with 3NM separation	5	7	2
FIS – without separation service	3	5	1

Note: FAA AC No: 20-165 of 2010 contains a sample guide for airworthiness approval of airborne ADS-B OUT equipment.
EASA documentation (AMC 20-24) can also be used as a reference for an NRA environment.

APPENDIX 3 - "PROPOSAL OF PUBLICATION OF A NATIONAL TECHNICAL STANDARD"

Example of a technical standard on the use of ADS-B for crews and technical personnel:

1. For aircraft with MODE-S transponders (1090/1090ES)

1.1 At present, ATS surveillance systems used in the State have 2 ways of automatically associating the FPLs to the aircraft identified by MSSR and ADS-B sensors, namely:

i. Mode A transponders
ii. Mode S transponders (1090/1090ES)

1.2 Crews using aircraft with Mode A transponders shall continue activating them, in accordance with the regulations and norms in force.

1.3 Crews using aircraft with Mode S/ADS-B OUT transponders (1090/1090ES) shall take into account the following:

1.3.1 The flight identification shall be correctly entered in the airborne data entry interface (CDTI, FMS, etc.), just as it was entered in box 7 of the FPL. Some airborne interfaces do not permit the change of flight ID after take-off, so it is recommended that special care be taken when using and entering information on this equipment.

1.3.2 The flight identification shall consist of the 3-letter designator of the company according to ICAO Doc 8585 and the flight number. In no case shall the IATA coding be used. If the flight number is not available (*e.g.,* private aircraft, general aviation, or aircraft to be moving only on the ground), the aircraft registration number shall be entered or, if an FPL has been filed, the identification specified in box 7 thereof.

1.3.3 Aircraft within ADS-B coverage (250 NM around the SCO VOR) shall keep the GNSS receiver on at all times; otherwise, the flight information in the ATC surveillance systems will be lost. If any contingency arises that forces the crew to turn off the GNSS receiver, the crew shall immediately report the occurrence to the corresponding ATC unit.

APPENDIX 4 – TABLES OF AIRBORNE AND GROUND ADS-B TRANSMITTER AND RECEIVER CLASSES

Table 2-1: ADS-B Aircraft System Classes
(adapted from RTCA DO-242A, Table 3-1)

Class	Subsystem	Example Applications	Features	Comments
Interactive Aircraft/Vehicle Participant Systems (Class A)				
A0	Minimum Interactive Aircraft/Vehicle	Enhanced Visual Acquisition, conflict detection	Lower transmit power and less sensitive receive than Class A1.	Minimum interactive capability with CDTI.
A1	Basic Interactive Aircraft	A0 Plus Airborne Conflict Management, station keeping	Standard transmit power and more sensitive receiver. Antenna Diversity (Note)	Provides ADS-B based conflict avoidance and interface to current TCAS surveillance algorithms/displays.
A2	Enhanced Interactive Aircraft	A1 Plus merging, conflict management, in-trail climb	Standard transmit power and more sensitive receiver. Interface with avionics source required for aircraft trajectory intent data. Antenna Diversity (Note)	Baseline for separation management employing intent information.
A3	Extended Interactive Aircraft	A2 Plus long range conflict management	More sensitive receiver. Interface with avionics source required for aircraft trajectory intent data. Antenna Diversity (Note)	Extends planning horizon for strategic separation employing intent information.
Broadcast-Only Participant Systems (Class B)				
B0	Aircraft Broadcast Only	Supports enhanced visual acquisition and conflict detection.	Transmit power may be matched to coverage needs. Nav data input required.	Enables aircraft to be seen by Class A and Class C users.
B1	Aircraft Broadcast Only	Supports B0 applications plus airborne conflict management and station keeping.	Transmit power may be matched to coverage needs. Nav data input required. Antenna Diversity (Note)	Enables aircraft to be seen by Class A and Class C users.
B2	Ground Vehicle Broadcast Only	Supports visual acquisition and conflict avoidance on airport surface.	Transmit power matched to surface coverage needs. High accuracy Nav data input required.	Enables vehicle to be seen by Class A and Class C users.
B3	Fixed Obstacle	Supports visual acquisition and conflict avoidance.	Fixed coordinates. No Nav data input required. Collocation with obstacle not required with appropriate broadcast coverage.	Enables Nav hazard to be detected by Class A users.
Ground Receive Systems (Class C)				
C1	ATS En Route and Terminal Area Operations	Supports ATS cooperative surveillance.	Requires ATS certification and interface to ATS sensor fusion system.	En Route coverage out to 200 NM. Terminal coverage out to 60 NM
C2	ATS Parallel Runway and Surface Operation	Supports ATS cooperative surveillance.	Requires ATS certification and interface to ATS sensor fusion system.	Expected approach coverage out to 30 NM, or the point where the aircraft intercepts the final approach course. Surface coverage out to 5 NM
C3	Flight Following Surveillance	Supports private user operations planning and flight following.	Does not require ATS interface. Certification requirements determined by user application.	Coverage determined by application.

Notes:

1. *See §3.3.1 for Antenna Diversity.*
2. *All ADS-B Class A, B0 and B1 systems are also intended to support the Air-to-Ground ATC Surveillance applications.*

Table 2-3: ADS-B Class A Transmitter Equipment To Message Coverage

Transmitter Class	Minimum Transmit Power (at Antenna Port)	Example Operation	MASPS Requirement (RTCA DO-242A)	Minimum Message Capability Required (From Table 2-2)
A0 (Minimum)	70 W	• Aid to Visual Acquisition • Conflict Avoidance	SV MS	Airborne Position A/C Identification & Type Airborne Velocity A/C Operational Status Extended Squitter A/C Status
		• Airport Surface	SV MS	Surface Position A/C Identification & Type A/C Operational Status Extended Squitter A/C Status
A1 (Basic)	125 W	• Aid to Visual Acquisition • Conflict Avoidance • Simultaneous Approaches	SV MS	Airborne Position A/C Identification & Type Airborne Velocity A/C Operational Status Extended Squitter A/C Status
		• Airport Surface	SV MS	Surface Position A/C Identification & Type A/C Operational Status Extended Squitter A/C Status
A2 (Enhanced)	125 W	• Aid to Visual Acquisition • Conflict Avoidance • Separation Assurance and Sequencing • Flight Path Deconfliction Planning • Simultaneous Approaches	SV MS TS TC+0	Airborne Position A/C Identification & Type Airborne Velocity A/C Operational Status Extended Squitter A/C Status Target State and Status Reserved for TC Message
		• Airport Surface	SV MS	Surface Position A/C Identification & Type A/C Operational Status Extended Squitter A/C Status
A3 (Extended)	125 W	• Aid to Visual Acquisition • Conflict Avoidance • Separation Assurance and Sequencing • Flight Path Deconfliction Planning • Simultaneous Approaches	SV MS TS TC+n	Airborne Position A/C Identification & Type Airborne Velocity A/C Operational Status Extended Squitter A/C Status Target State and Status Reserved for TC Message
		• Airport Surface	SV MS	Surface Position A/C Identification & Type A/C Operational Status Extended Squitter A/C Status

Table 2-4: ADS-B Class B Transmitter Equipment To Message Coverage

Transmitter Class	Minimum Transmit Power (at Antenna Port)	Example Operation	MASPS Requirement (RTCA DO-242A)	Minimum Message Capability Required (From Table 2-2)
B0 (Aircraft)	70 W [1]	• Aid to Visual Acquisition • Conflict Avoidance	SV MS	Airborne Position A/C Identification & Type Airborne Velocity A/C Operational Status Extended Squitter A/C Status
		• Airport Surface		Surface Position A/C ID and Type A/C Operational Status Extended Squitter A/C Status
B1 (Aircraft)	125 W [1]	• Aid to Visual Acquisition • Conflict Avoidance	SV MS	Airborne Position A/C Identification & Type Airborne Velocity A/C Operational Status Extended Squitter A/C Status
		• Airport Surface		Surface Position A/C Identification and Type A/C Operational Status Extended Squitter A/C Status
B2 (Ground Vehicle)	70 W [1]	• Aid to Visual Acquisition • Conflict Avoidance • Airport Surface	SV MS	Surface Position A/C Identification & Type A/C Operational Status
B3 (Fixed Obstacle)	70 W [1]	• Aid to Visual Acquisition • Conflict Avoidance • Airport Surface	SV MS	Airborne Position A/C Identification & Type A/C Operational Status

[1] – May be increased based upon application specific needs.

Notes: *(Table 2-3 and Table 2-4):*

1. *SV = State Vector, MS = Mode Status, TS = Target State, TC = Trajectory Change*
2. *SV elements are specified in Table 2-81.*
3. *MS elements are specified in Table 2-88.*

Table 2-5: ADS-B Class A Receiver Equipment To Report Coverage

Receiver Class	Minimum Trigger Threshold Level (MTL)	Reception Technique	Example Operation	MASPS Requirement [RTCA DO-242A Table 3-3(a)]	Minimum Report Required
A0 (Basic VFR)	-72 dBm	Standard	• Aid to Visual Acquisition • Airport Surface	SV MS	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2)
A1 (Basic IFR)	-79 dBm	Enhanced (§2.2.4.4)	• Aid to Visual Acquisition • Conflict Avoidance • Simultaneous Approaches • Airport Surface	SV MS ARV	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Air Referenced Velocity Report (ARV) (§2.2.8.3.2)
A2 (Enhanced IFR)	-79 dBm	Enhanced (§2.2.4.4)	• Aid to Visual Acquisition • Conflict Avoidance • Separation Assurance and Sequencing • Simultaneous Approaches • Airport Surface	SV MS TS ARV TC+0	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Reports
A3 (Extended Capability)	-84 dBm	Enhanced (§2.2.4.4)	• Aid to Visual Acquisition • Conflict Avoidance • Separation Assurance and Sequencing • Flight Path Deconfliction Planning • Simultaneous Approaches • Airport Surface	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Reports

Table 2-6: ADS-B Class C Receiver Equipment To Report Coverage

Receiver Class	Minimum Trigger Threshold Level (MTL)	Operation	MASPS Requirement [RTCA DO-242A Table 3-3(b)]	Minimum Report Required
C1 (ATS En Route and Terminal)	Not Specified in these MOPS	• Aid to Visual Acquisition • Conflict Avoidance • Separation Assurance and Sequencing • Flight Path Deconfliction Planning	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Report(s)
C2 (Approach and Surface)	Not Specified in these MOPS	• Aid to Visual Acquisition • Conflict Avoidance • Separation Assurance and Sequencing • Simultaneous Approaches • Airport Surface	SV MS TS ARV TC+n	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2) AND ADS-B Target State Report (§2.2.8.3.1) AND ADS-B ARV Report (§2.2.8.3.2) AND Reserved for ADS-B Trajectory Change Report(s)
C3 (Flight Following)	Not Specified in these MOPS	• Aid to Visual Acquisition • Separation Assurance and Sequencing • Airport Surface	SV MS	ADS-B State Vector Report (§2.2.8.1) AND ADS-B Mode Status Report (§2.2.8.2)

Note: *(Table 2-5 and Table 2-6):*

SV = State Vector, MS = Mode Status, OC = On-Condition TS = Target State, ARV = Air Referenced Velocity, TC = Trajectory Change

APPENDIX 5 – ASPECTS THAT OPERATORS SHOULD TAKE INTO ACCOUNT WHEN OPERATING AN ADS-B TRANSPONDER

- In the early stages of these implementations, crews normally incur in frequent errors when entering the flight/aircraft identification or ACID (aircraft ID) in the airborne interface. Both the ELS and ES (1090 ES) functions of the Mode S transponder emit the flight identification information entered on board. This identification should be the same as the one shown in box 7 of the ICAO flight plan. This same data, when transmitted, is called "target identification" (or "tid") with the data reference number of I021/170 of the ASTERIX protocol, category 21, in the message formats processed by the control centre.

- For aircraft privately operated, the flight ACID should reflect the aircraft registration (*e.g.*, OB123G). In this case, consideration should be given to physical coding of the flight identification (on the same transponder, for example, during initial installation), with the corresponding registration number, to avoid the need for an input interface in the cockpit and to ensure the integrity of the information. The coding of the flight identification should be checked during installation and initial testing.

- When the flight ACID changes (*e.g.*, airline operations), an interface to enter the flight ACID will be required in the cockpit. In this case, the flight identification should be the ICAO 3-letter airline designator, followed by the flight number. The input interface should be checked to ensure proper flight ACID coding during installation and initial testing.

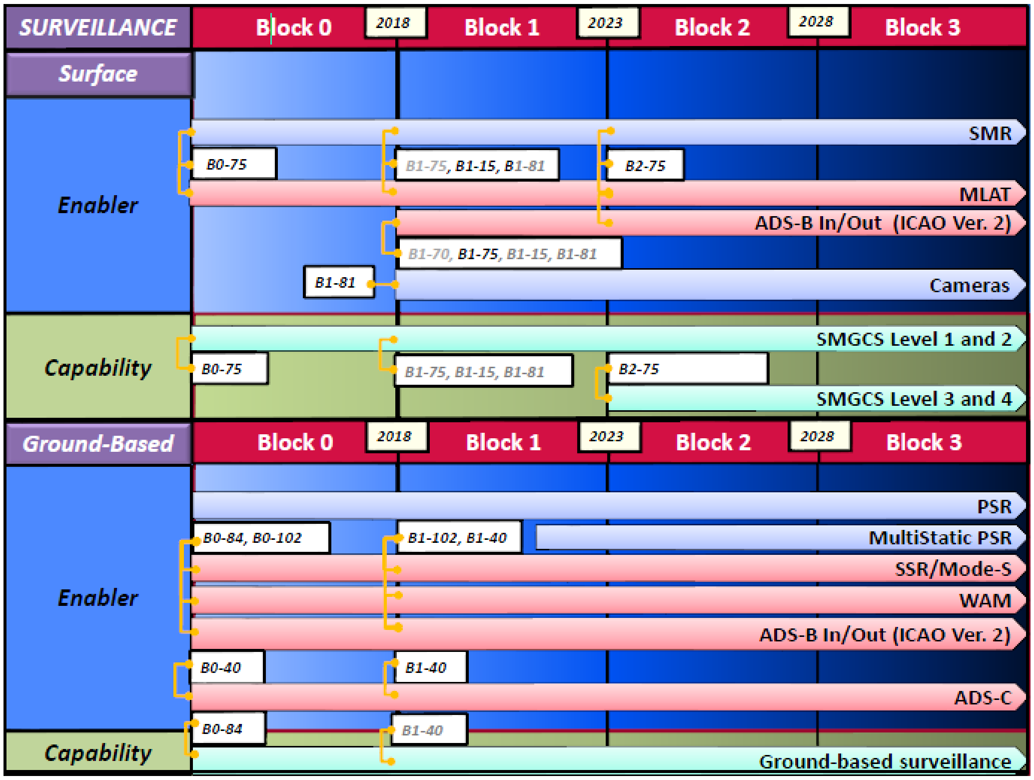
- It has been noted that some aircraft models have an ACID blocking system in the airborne interface to avoid changes to the flight identification.

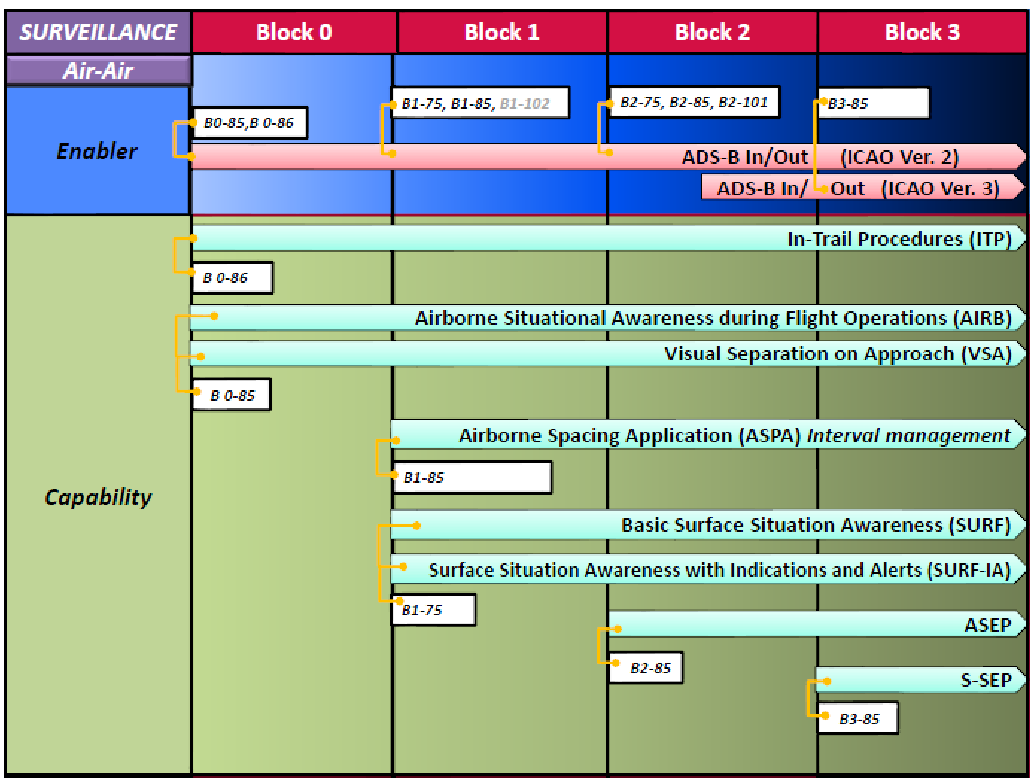
- This setup, sometimes known as WOW (Weight On Wheels), shall be taken into account by operators and ANSPs to alert crews about on-board interface operation, so as to reduce the problems they cause to the ATC system. It is recommended that straightforward operation manuals and checklists be produced on this topic, especially during implementation phases.

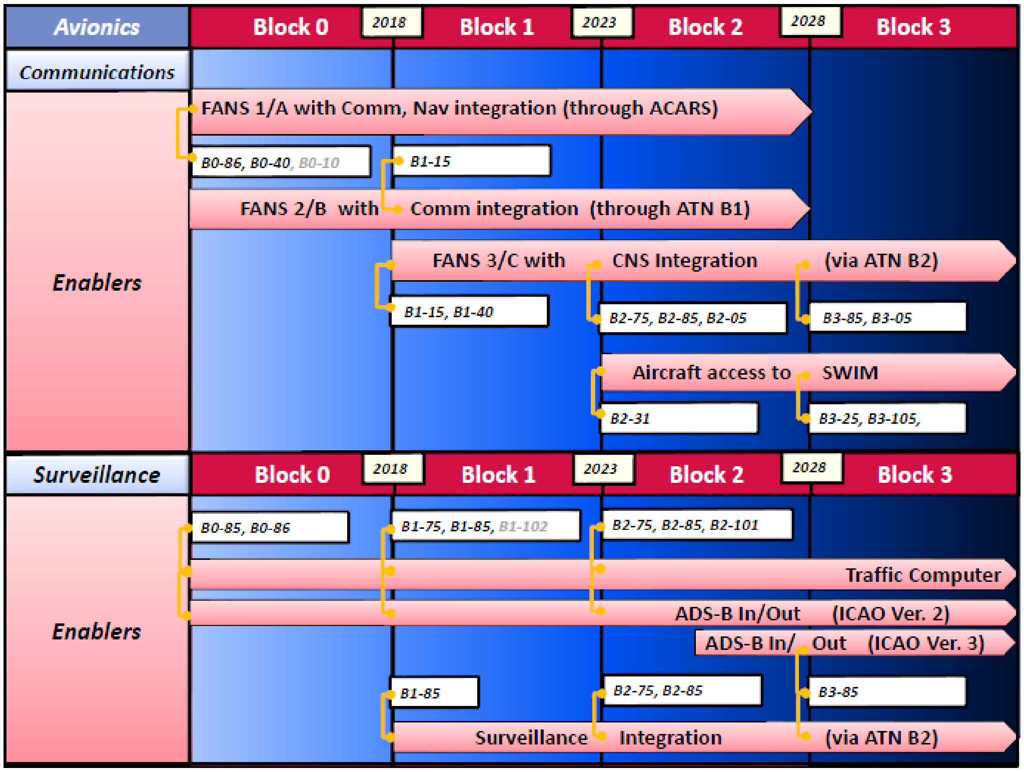
- Some problems caused by flights with incorrect ACIDs are: inability to automatically correlate flight plans with ADS-B blips, correlation with an incorrect FPL, increased controller workload and thus reduced ATC capacity, unforeseen delays, frequency saturation, failure to process prediction or MTCD alerts, etc.

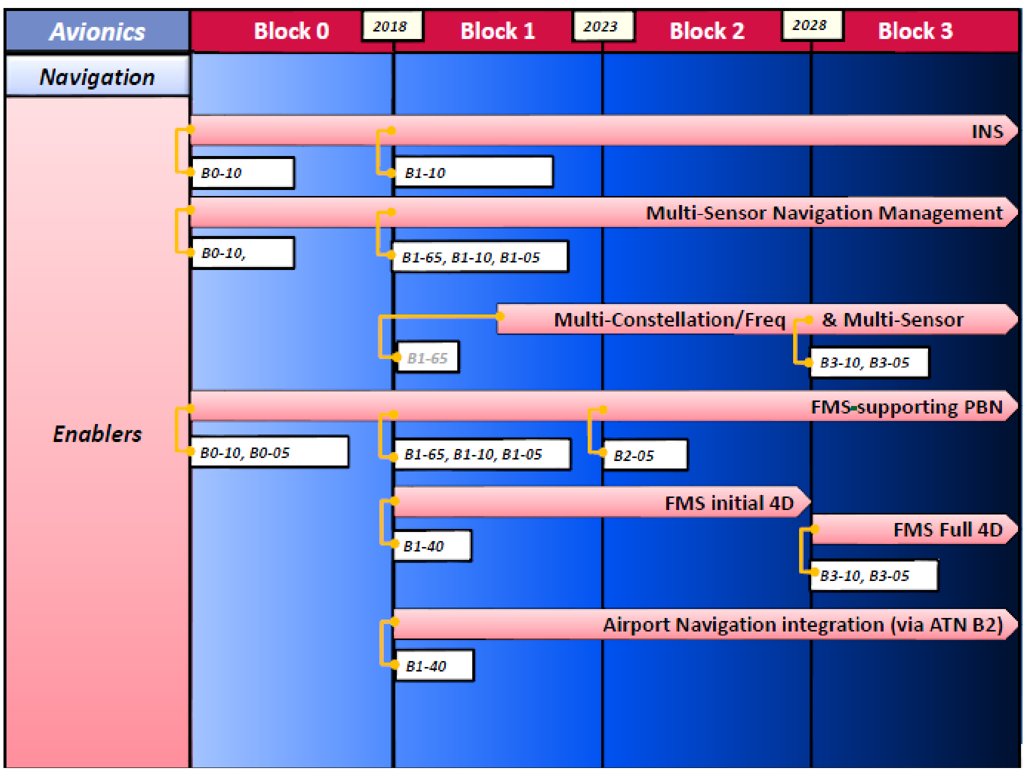
- It is expected that, during the initial ADS-B implementation phases, crew workload will increase upon ensuring entry of the right data, since they will be using different identifications (*e.g.*, ICAO-IATA) at different points in time.

APPENDIX 6 – ASBU METHODOLOGY SURVEILLANCE "ROADMAP"






Avionics
Block 0
2018
Block 1
2023
Block 2
2028
Block 3
Communications
Enablers
FANS 1/A with Comm, Nav integration (through ACARS)
B0-86, B0-40, B0-10
B1-15
FANS 2/B with Comm integration (through ATN B1)
FANS 3/C with CNS Integration (via ATN B2)
B1-15, B1-40
B2-75, B2-85, B2-05
B3-85, B3-05
Aircraft access to SWIM
B2-31
B3-25, B3-105,
Surveillance
Block 0
2018
Block 1
2023
Block 2
2028
Block 3
Enablers
B0-85, B0-86
B1-75, B1-85, B1-102
B2-75, B2-85, B2-101
Traffic Computer
ADS-B In/Out (ICAO Ver. 2)
ADS-B In/ Out (ICAO Ver. 3)
B1-85
B2-75, B2-85
B3-85
Surveillance Integration (via ATN B2)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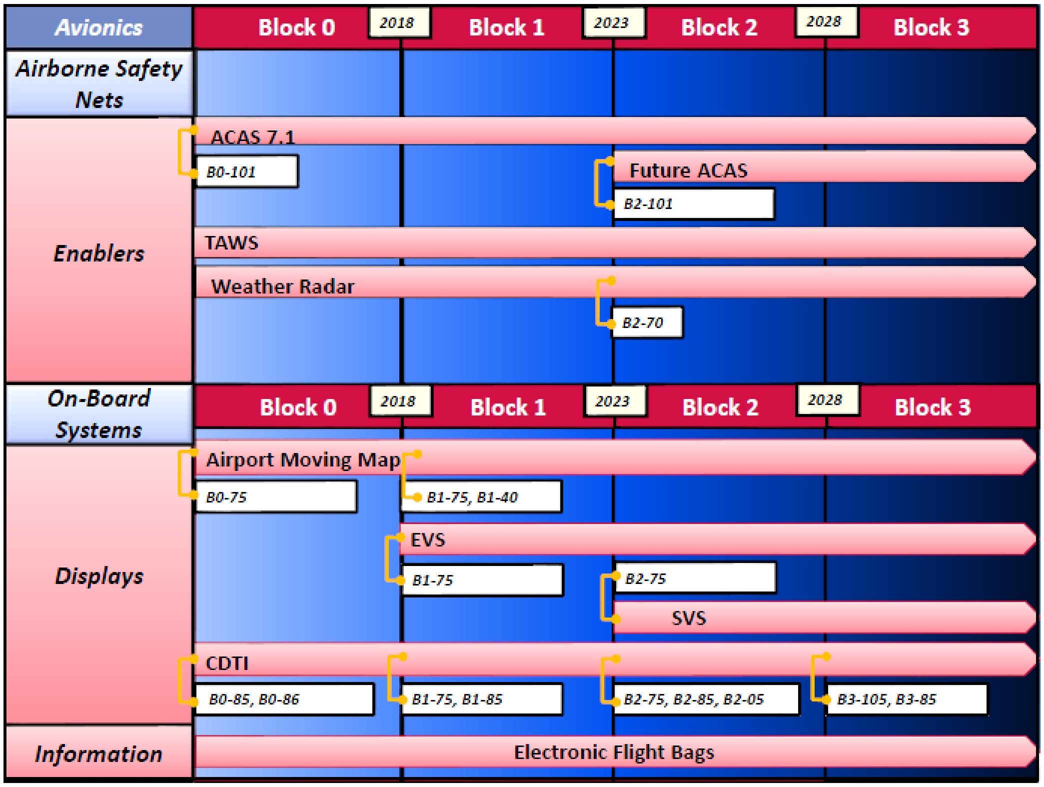
Block 0
2018
Block 1
2023
Block 2
2028
Block 3
Navigation
Enablers
INS
B0-10
B1-10
Multi-Sensor Navigation Management
B0-10,
B1-65, B1-10, B1-05
Multi-Constellation/Freq & Multi-Sensor
B1-65
B3-10, B3-05
FMS-supporting PBN
B0-10, B0-05
B1-65, B1-10, B1-05
B2-05
FMS initial 4D
B1-40
FMS Full 4D
B3-10, B3-05
Airport Navigation integration (via ATN B2)
B1-40



Avionics
Block 0
2018
Block 1
2023
Block 2
2028
Block 3
Airborne Safety Nets
Enablers
ACAS 7.1
B0-101
Future ACAS
B2-101
TAWS
Weather Radar
B2-70
On-Board Systems
Block 0
2018
Block 1
2023
Block 2
2028
Block 3
Displays
Airport Moving Map
B0-75
B1-75, B1-40
EVS
B1-75
B2-75
SVS
CDTI
B0-85, B0-86
B1-75, B1-85
B2-75, B2-85, B2-05
B3-105, B3-85
Information
Electronic Flight Bags

APPENDIX 7 – SAM RADAR COVERAGE DIAGRAMS

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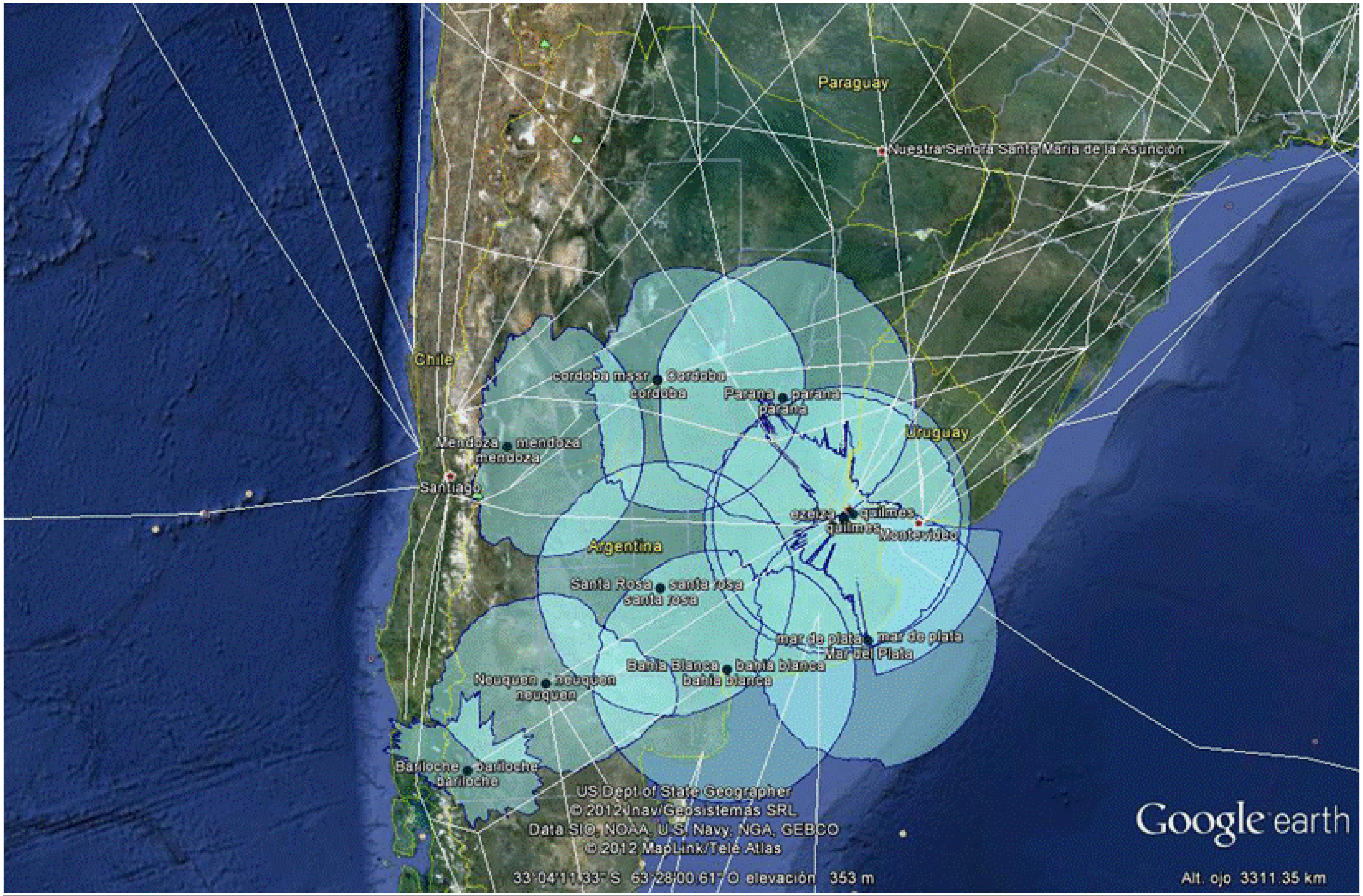

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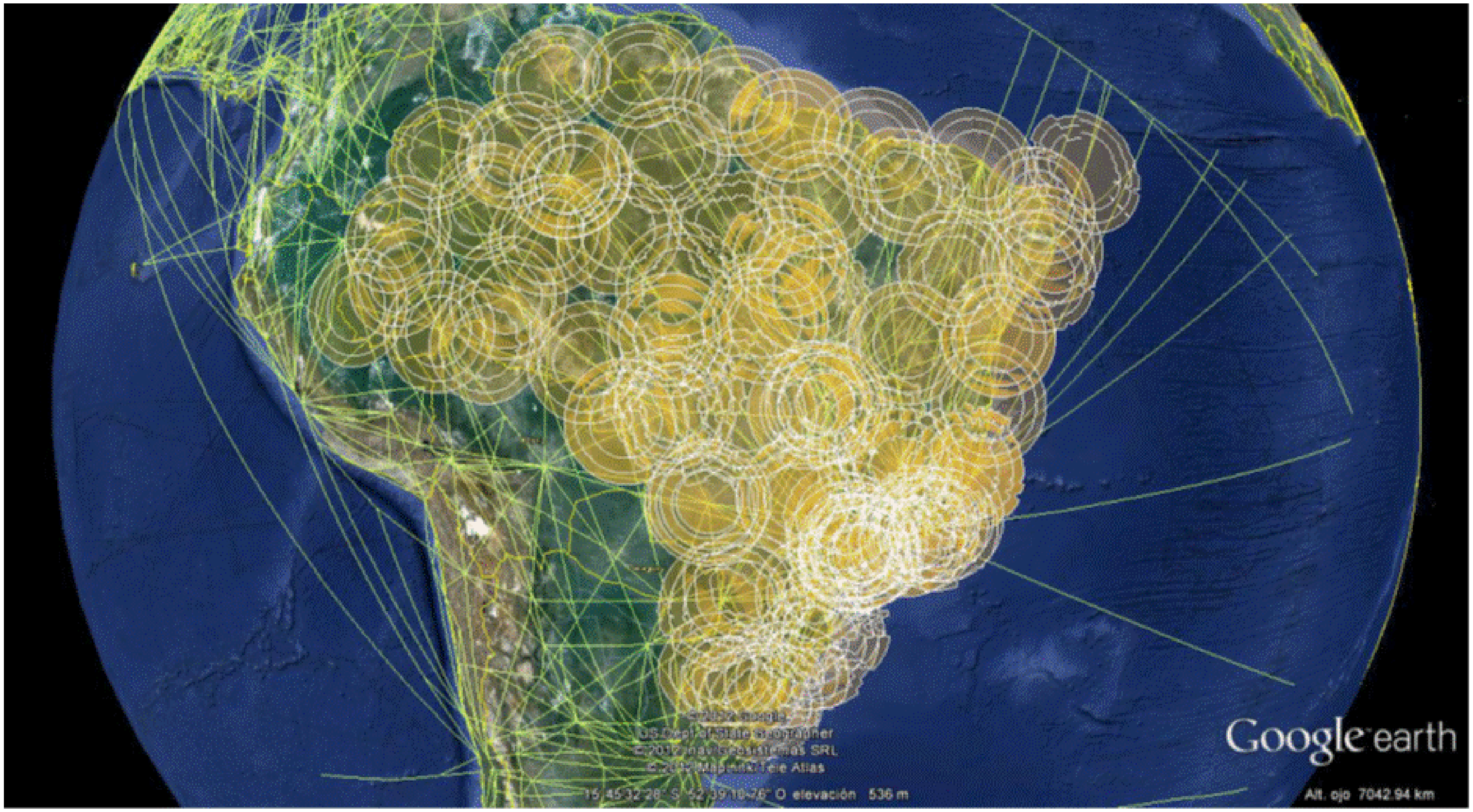

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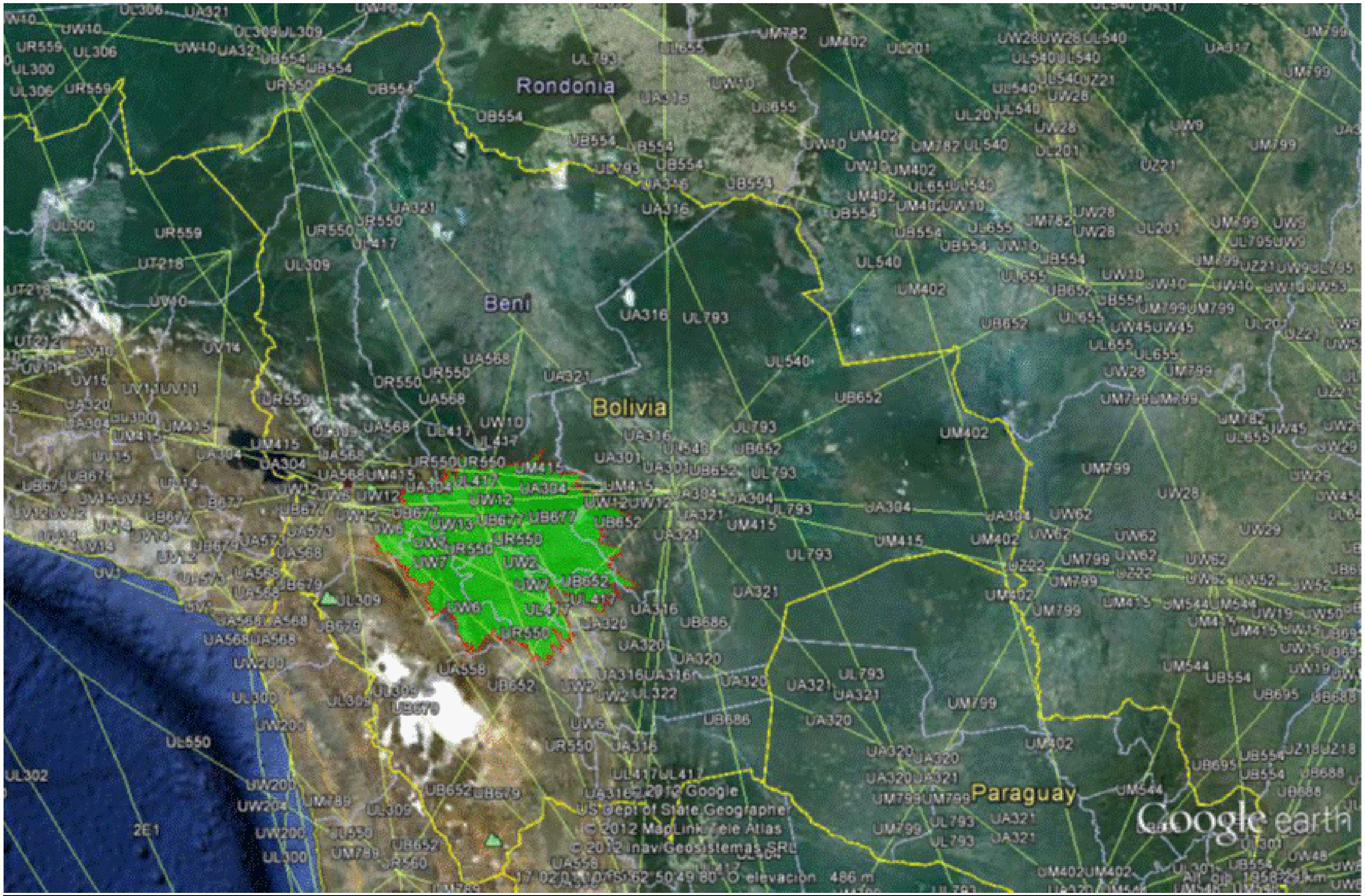

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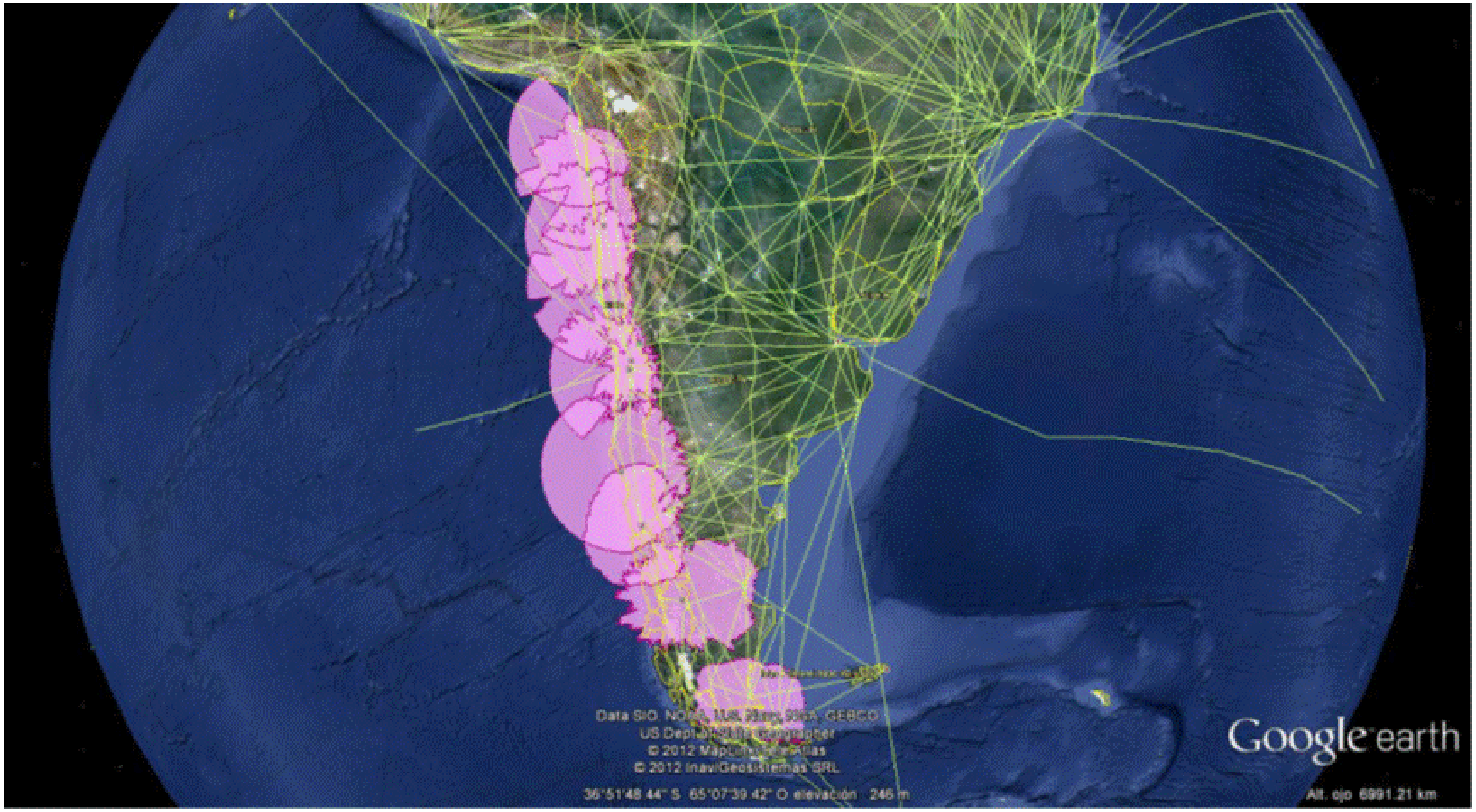
© 2012 Inav/Geosistemas SRL
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Google earth
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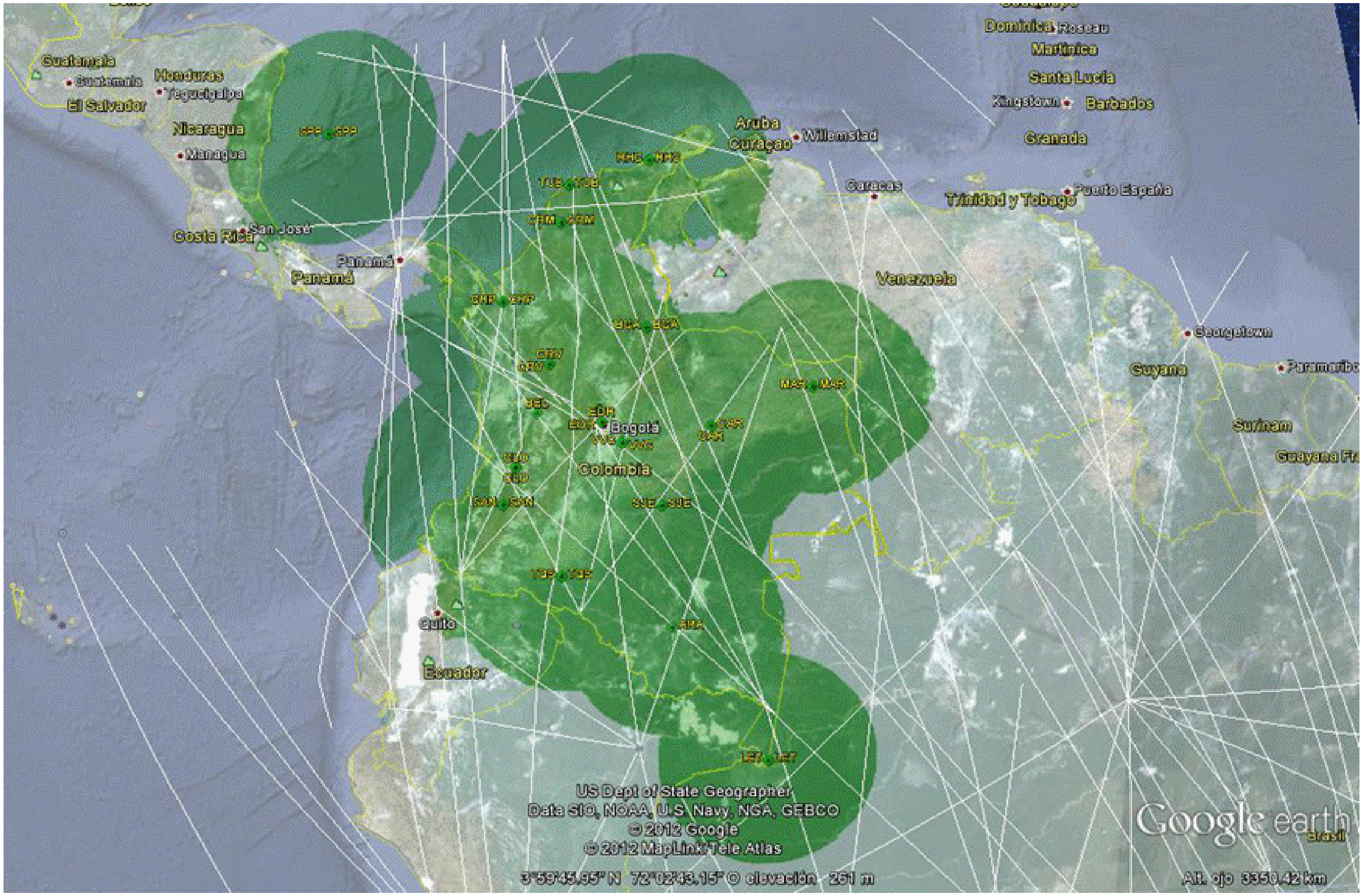

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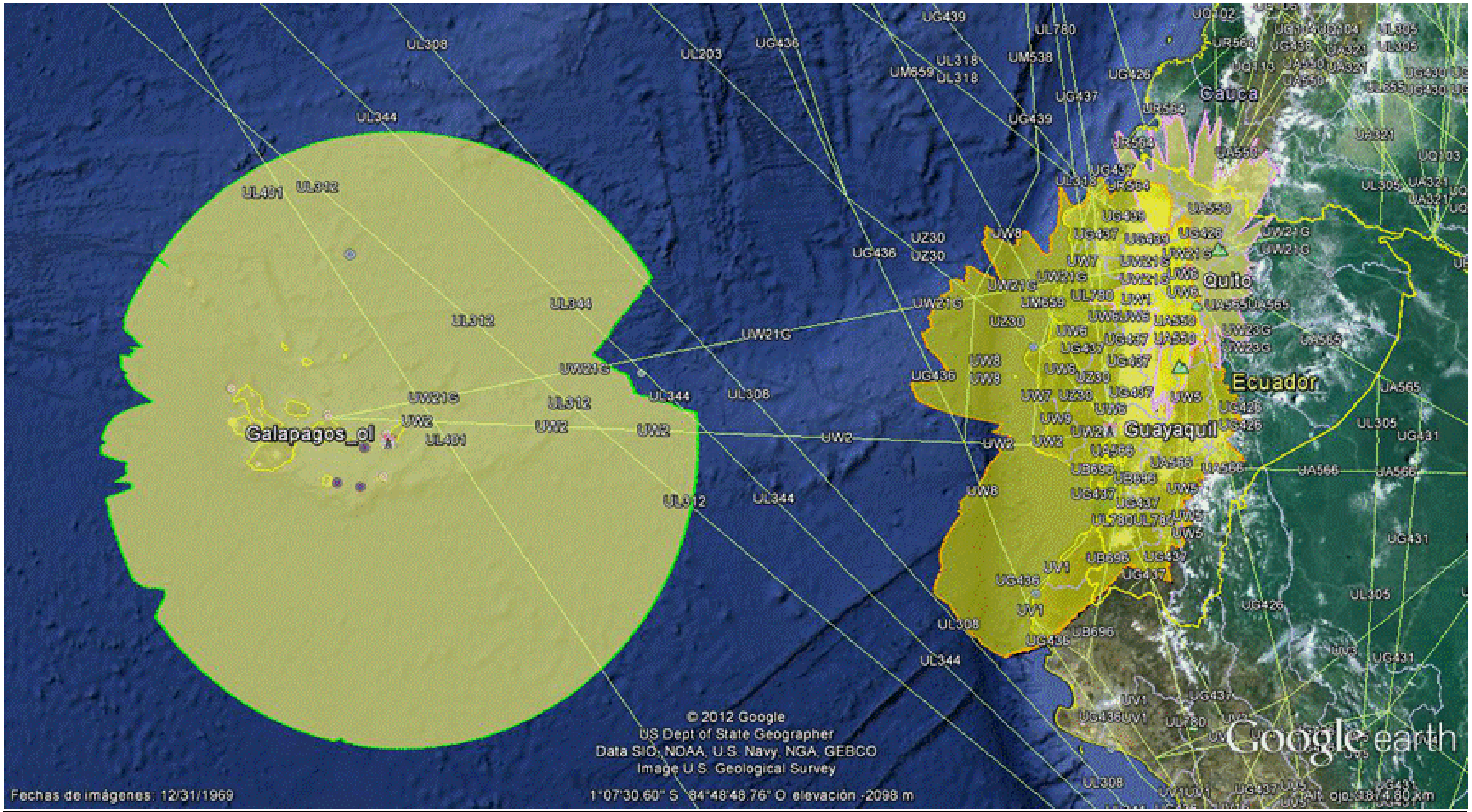

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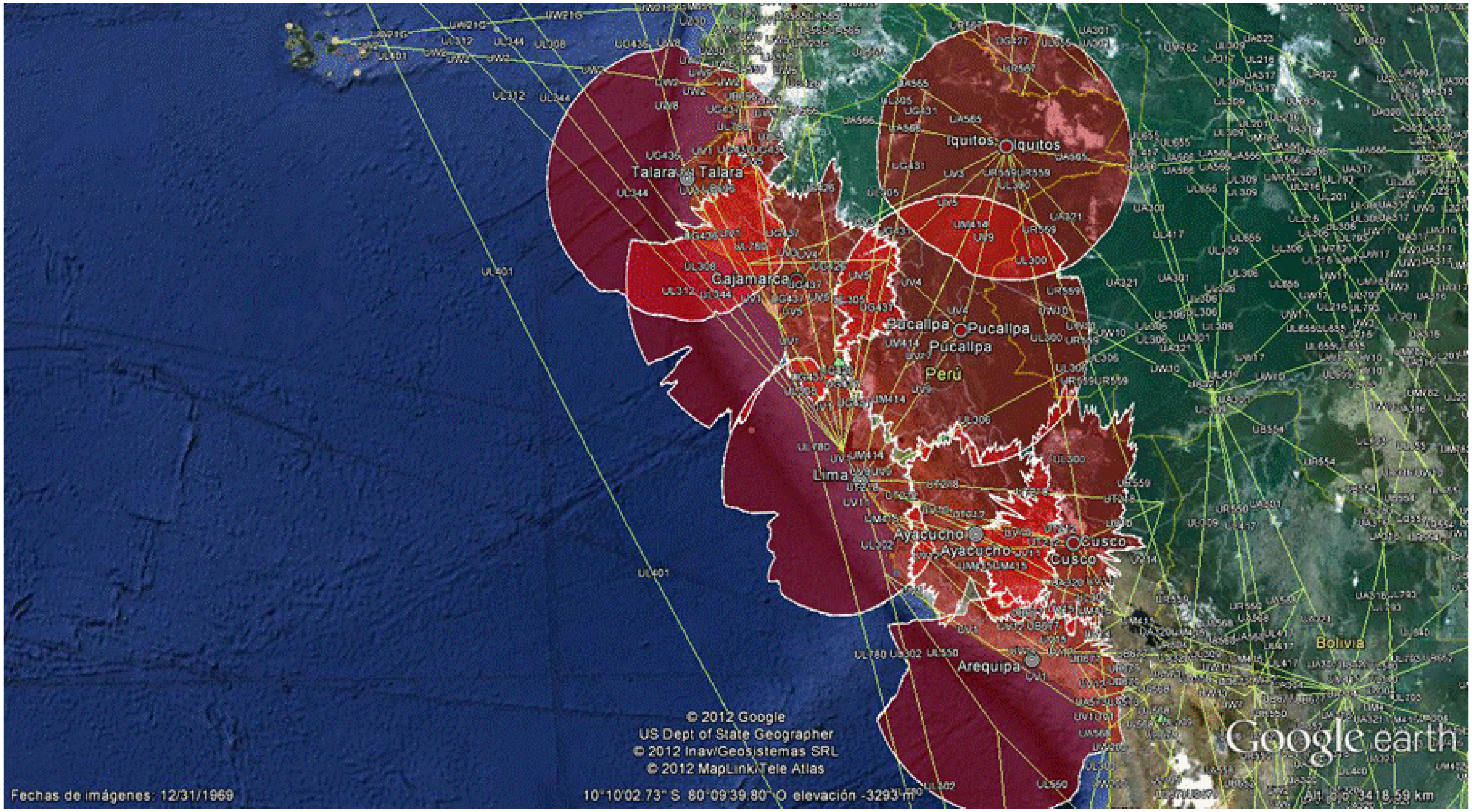
Talara
Cajamarca
Iquitos
Pucallpa
Perú
Lima
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Cusco
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Bolivia
© 2012 Google
US Dept of State Geographer
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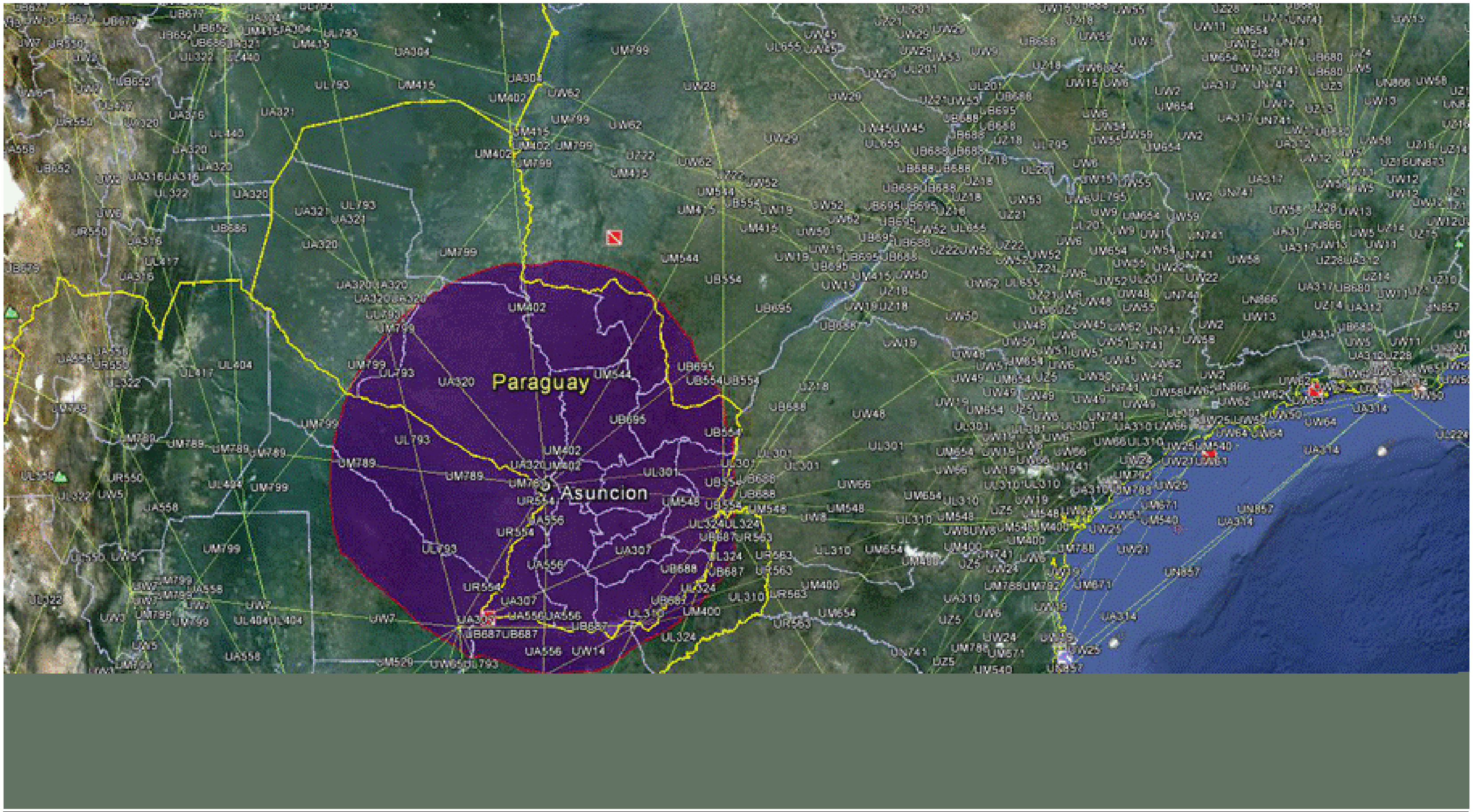
© 2012 MapLink/Tele Atlas
Google earth
Fechas de imágenes: 12/31/1969

PARAGUAY (FL250)



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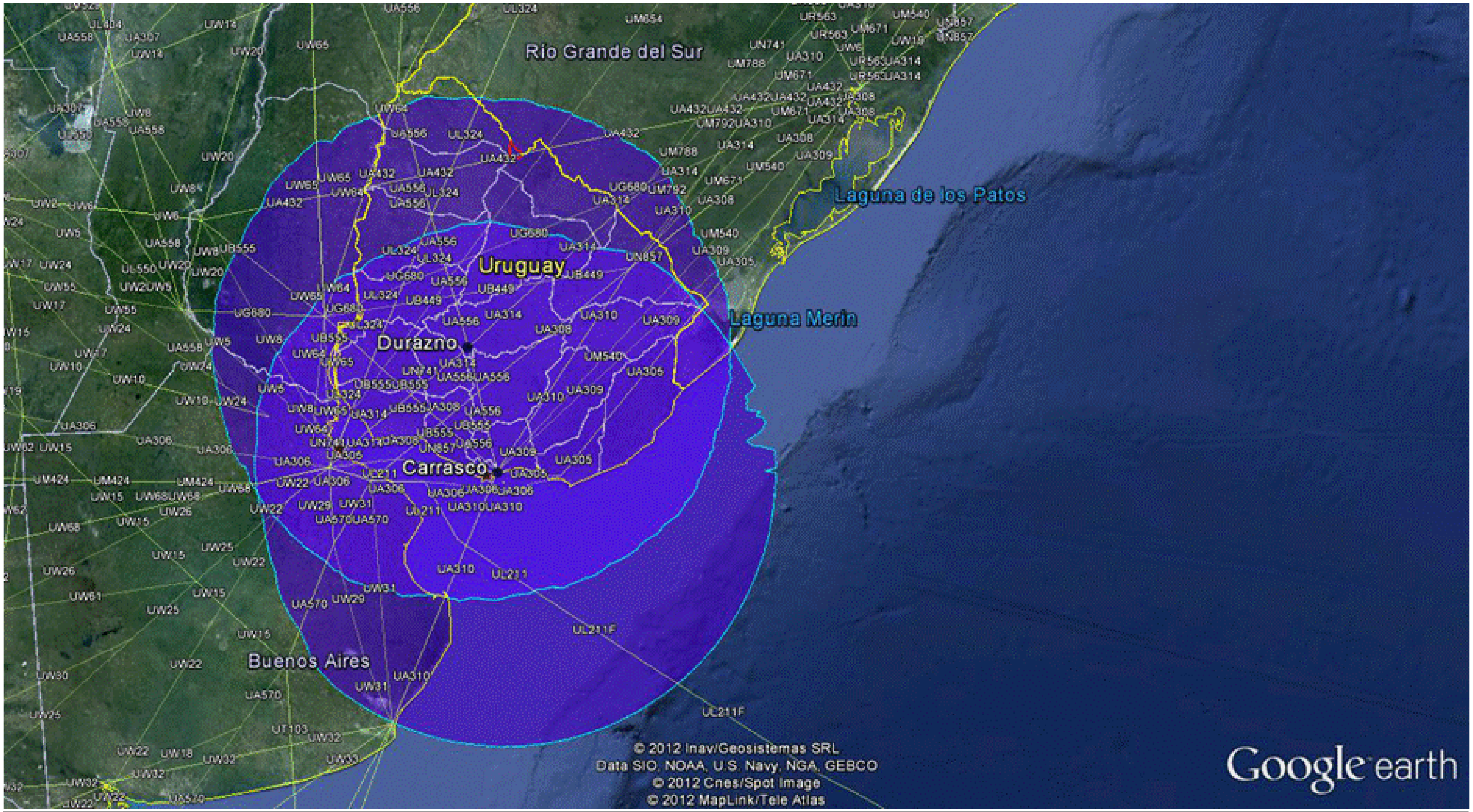

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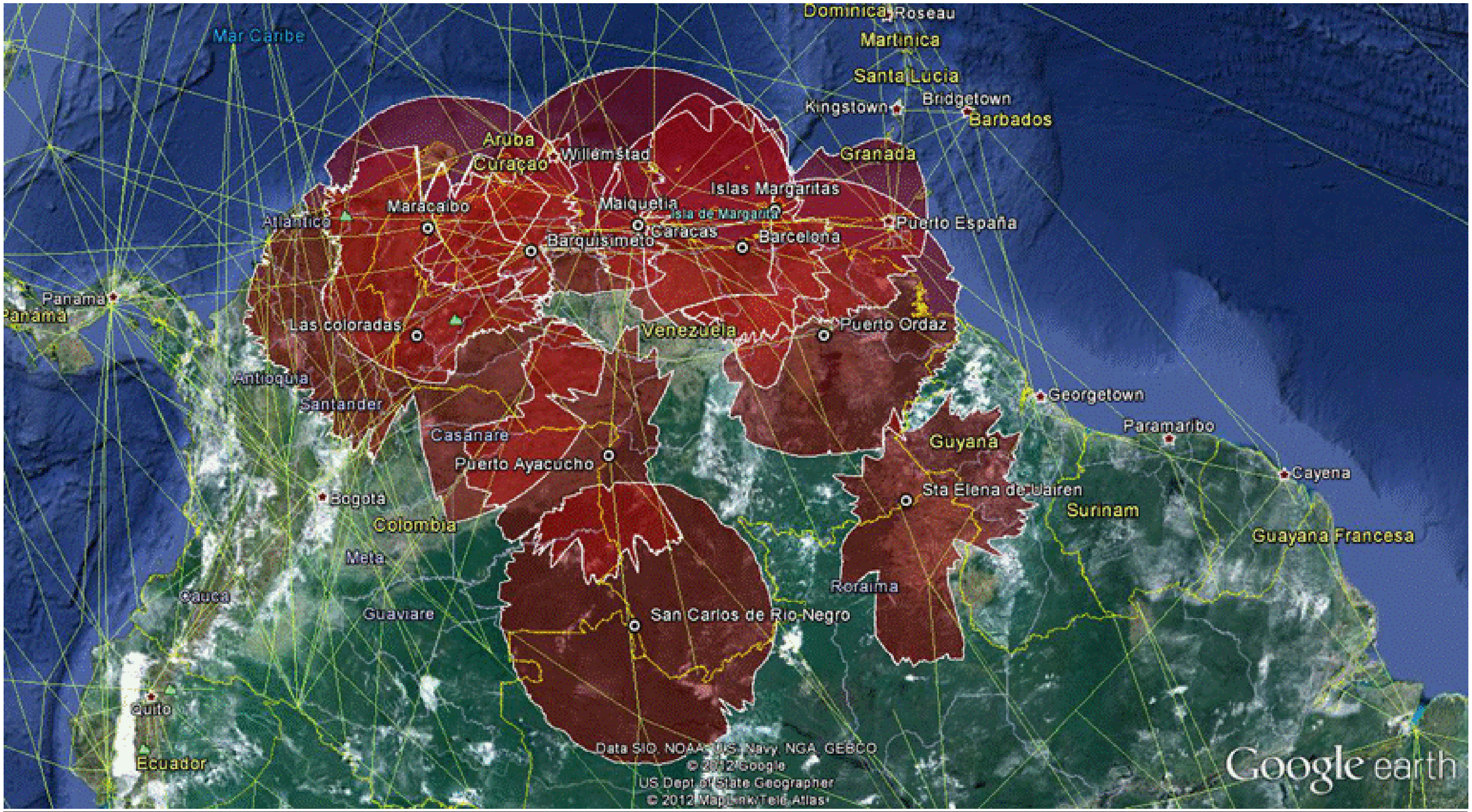
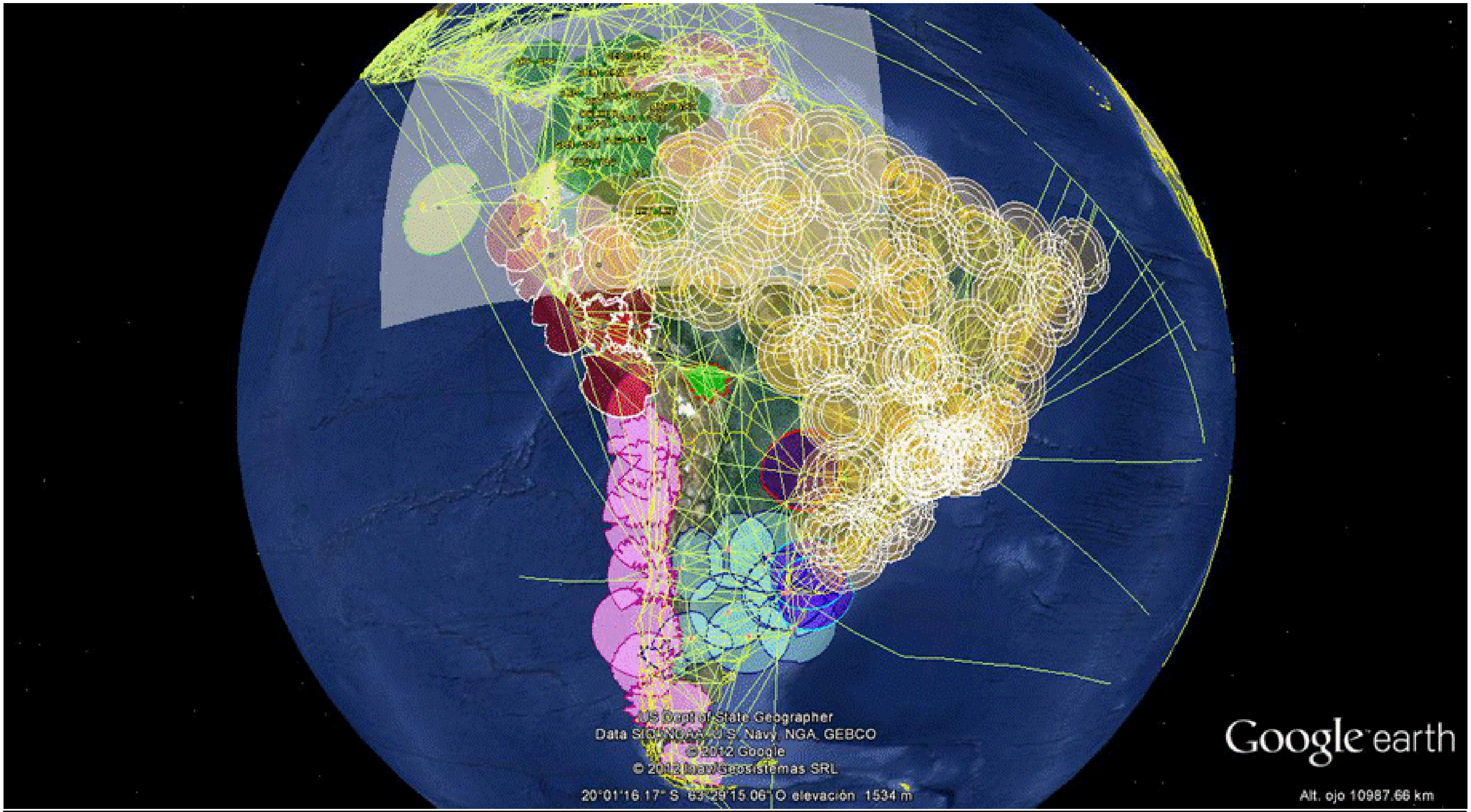


TOTAL SAM REGION



APPENDIX 8 – RECEIVER AUTONOMOUS INTEGRITY MONITORING SYSTEM - RAIM

Definitions and technical considerations

RAIM is a technology developed for assessing the integrity of the global positioning system (GPS) in a GPS receiver system. It is of special importance for critical GPS security applications, such as in aviation or maritime navigation.

In accordance with Doc 9849 AN/457 "GNSS Manual", the most common ABAS (AIRCRAFT-BASED AUGMENTATION SYSTEM) technique is the so-called RAIM (RECEIVER AUTONOMOUS INTEGRITY MONITORING).

For air navigation operations based on the global navigation satellite system (GNSS), Annex 10, Vol. I, Table 3.7.2.4.1 – Signal-in-space performance requirements for en-route, non-precision approach (NPA), approach with vertical guidance (APV), and terminal area operations supported by an aircraft-based augmentation system (ABAS), specifies that aircraft equipped with GPS receivers must have certified RAIM systems that meet the specified accuracy, integrity, and continuity parameter monitoring requirements.

Before starting its flight, every aircraft should check if RAIM is available throughout the route, and the corresponding ATS unit should also know what is the RAIM availability in its area of responsibility. RAIM operation is checked using a software application called RAIM availability prediction, which indicates the operating condition of the GPS constellation through messages called NANU (Notice Advisory to Navstar User).

States should be aware that RAIM algorithms require a minimum of five satellites on sight for fault detection (FD) and for detecting the presence of a position error that is unacceptably significant for a given flight mode. For fault detection and exclusion (FDE), a minimum of 6 satellites is used not only for detecting a defective satellite, but also for excluding it from the navigation solution so that the navigation function may proceed without interruption.

Likewise, operating limitations and conditions that will have an impact on RAIM availability values must be known. The RAIM system requires redundant satellite distance measurements to detect defective signals and alert the pilot, which means that the integrity navigation guide provided by RAIM cannot be available 100% of the time.

For receivers that cannot take advantage of selective availability (SA) interruption, the average RAIM availability is 99,99 % for en-route operations, and 99,7 % for non-precision approach operations with a constellation of 24 GPS satellites. FDE availability ranges from 99.8 % for en-route operations to 89.5 % for non-precision approach operations. For receivers that can take advantage of SA interruption (*e.g.*, SBAS receivers), RAIM availability increases to 100% for en-route operations and to 99.998 % for non-precision approach operations. FDE availability ranges from 99.92 % for en-route operations to 99.1% for non-precision approach operations.

RAIM and FDE availability will be slightly lower for medium latitude operations and slightly higher for equatorial and high latitude regions due to the nature of the orbits. The use of satellites from multiple GNSS constellations or SBAS satellites as additional sources of spacing can improve RAIM and FDE availability.

RAIM Prediction

GNSS differs from traditional navigation systems in that satellites and areas of degraded coverage are in constant change.

In this sense, if the satellite fails or is put out of service for maintenance, it is not immediately clear what areas of airspace will be affected, if any. The location and duration of these interruptions can be predicted with the help of computer analysis and reported to pilots during the pre-flight planning process. However, this prediction process is not fully representative of all RAIM implementations in the different receiver models. Prediction instruments are generally conservative and thus predict a lower availability than what is actually encountered in flight for protecting lower-level receiver models.

Since RAIM operates in an autonomous manner, that is, without the help of external signals, it requires redundant pseudorange measurements. In order to obtain a 3D position solution, at least four measurements are necessary. In order to detect a fault, at least 5 measurements are necessary, and to isolate and exclude a fault (FDE), at least 6 measurements are necessary. Nevertheless, more measurements are frequently needed based upon satellite geometry. Normally, there are between 7 and 12 satellites on sight.

Test statistics used are based on the residual pseudorange measurement (the difference between the expected measure and the observed measure) and the level of redundancy. Test statistics are compared with a threshold value, which is determined based on the required probability of false alarm (PFA) and the expected measurement noise. In aviation systems, the action platform is set to 1/15000.

The horizontal integrity limit (HIL) or horizontal protection limit (HPL) is a figure that represents the radius of a circle centred on the GPS position solution, and which is assured to contain the true position of the receiver within RAIM specifications (*i.e.*, it meets the Pfa and the Pmd). The HPL is calculated as a function of the RAIM threshold and satellite geometry at the time of the measurements. The HPL is compared to the horizontal alarm limit (HAL) to determine if RAIM is available.

Regional actions concerning RAIM implementation

The SAM Region has been considering the need to have a RAIM prediction system, mainly in the SAM implementation group (SAMIG). Within this context, the Lima Regional Office circulated a letter asking SAM States about their willingness to have a regional RAIM system; most States responded their agreement.

As to the development of a RAIM availability prediction system for the SAM Region, a technical and financial solution was presented at the seventh workshop/meeting of the SAM Implementation Group (SAM/IG/7).

The SAM RAIM availability prediction programme would be placed in dual servers and would be accessed by users through the web, at an address to be determined. The application would be available 24/7 with availability in the order of 99.5%.

Two modalities have been considered for the implementation of RAIM availability prediction: one in which the programme would be installed and managed at the manufacturer´s premises, and the other in which the programme as well as the required software would be installed at a location in the Region under the supervision of the manufacturer or the service provider. In both modalities, the user would access the information through an Internet website hosting the RAIM availability prediction programme.

The implementation of a regional RAIM prediction programme would allow all the States of the Region to have a single programme where all operators could consult en-route, terminal, and approach PBN procedures.

APPENDIX 9 - ASTERIX CATEGORY 21 ED 1.8

Table 1 - Data Items of Category 021

Data Item Reference Number	Description	Resolution
I021/008	Aircraft Operational Status	N.A.
I021/010	Data Source Identification	N.A.
I021/015	Service Identification	N.A.
I021/016	Service Management	N.A.
I021/020	Emitter Category	N.A.
I021/040	Target Report Descriptor	N.A.
I021/070	Mode 3/A Code	N.A.
I021/071	Time of Applicability for Position	1/128 s
I021/072	Time of Applicability for Velocity	1/128 s
I021/073	Time of Message Reception for Position	1/128 s
I021/074	Time of Message Reception for Position – High Precision	2^{-30} s
I021/075	Time of Message Reception for Velocity	1/128 s
I021/076	Time of Message Reception for Velocity – High Precision	2^{-30} s
I021/077	Time of Report Transmission	1/128 s
I021/080	Target Address	N.A.
I021/090	Quality Indicators	N.A.
I021/110	Trajectory Intent	N.A.
I021/130	Position in WGS-84 co-ordinates	$180/2^{23}$ °
I021/131	Position in WGS-84 co-ordinates, high resolution	$180/2^{30}$ °
I021/132	Message Amplitude	1 dBm
I021/140	Geometric Height	6.25 ft
I021/145	Flight Level	¼ FL
I021/146	Intermediate State Selected Altitude	25 ft
I021/148	Final State Selected Altitude	25 ft
I021/150	Air Speed	N.A.
I021/151	True Air Speed	N.A.
I021/152	Magnetic Heading	$360/2^{16}$ °
I021/155	Barometric Vertical Rate	6.25 ft / min
I021/157	Geometric Vertical Rate	6.25 ft / min
I021/160	Ground Vector	N.A.
I021/161	Track Number	N.A.
I021/165	Track Angle Rate	1/32 °/s
I021/170	Target Identification	N.A.
I021/200	Target Status	N.A.
I021/210	MOPS Version	N.A.
I021/220	Met Information	N.A.
I021/230	Roll Angle	0.01 deg
I021/250	Mode S MB Data	N.A.
I021/260	ACAS Resolution Advisory Report	N.A.
I021/271	Surface Capabilities and Characteristics	N.A.
I021/295	Data Ages	N.A.
I021/400	Receiver ID	N.A.