REVIEW ARTICLE

Regulation for ADS-B[1] in Brazilian airspace

Regulación para ADS-B[1] en el espacio aéreo brasileño

Regulação para o ADS-B[1] no espaço aéreo brasileiro

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ABSTRACT

The Automatic Dependent Broadcasting Surveillance (ADS-B) is a well-known technology, internationally standardized and recognized as an inexpensive way to carry out radar-like surveillance, even in places where conventional radar surveillance is not adequate. The implementation of this technology means the introduction of new monitored airspace configurations and new operational capabilities. The regulation of the Department of Airspace Control (DECEA) and the National Civil Aviation Agency (ANAC) should provide adequate processes for civil aviation operations in order to face this evolutionary stage, improving concepts and adapting procedures. This study, whose objective is to contribute to the strengthening of the regulation that will support ADS-B in Brazil, was developed based on a hypothetical-deductive method, which included literature review, unstructured interviews of the focused type, international benchmarking and case study of ADS-B national implementation. The results showed the identification of possible regulatory improvements with a positive impact on the implementation of ADS-B in national airspace, to be subject to further verification and discussion.

Keywords: ADS-B. Regulation. Surveillance. Civil Aviation.

RESUMEN

La vigilancia de Radiodifusión Dependiente Automática (ADS-B) es una tecnología bien conocida, estandarizada internacionalmente y reconocida como una forma económica de llevar a cabo vigilancia tipo radar, incluso en lugares donde la vigilancia por radar convencional no es adecuada. La implementación de esta tecnología significa la introducción de nuevas configuraciones del espacio aéreo monitoreado y nuevas capacidades operativas que deben ser entendidas por la comunidad aeronáutica y la regulación del Departamento de Control del Espacio Aéreo (DECEA) y la Agencia Nacional de Aviación Civil (ANAC) debe proporcionar procesos adecuados. para las operaciones de la aviación civil para afrontar esta etapa evolutiva, mejorando conceptos y adaptando procedimientos. Este estudio, cuyo objetivo es contribuir al fortalecimiento de la regulación que apoyará a ADS-B en Brasil, fue desarrollado con un enfoque multimetodológico, incluyendo revisión de literatura, consulta de expertos, benchmark internacional y estudio de caso, y resultó en el identificación de 15 posibles mejoras regulatorias con impacto positivo en la implementación de ADS-B en el espacio aéreo nacional.

Palabras clave: *ADS-B. Regulación. Vigilancia. Aviación Civil.*

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The acronyms and abbreviations contained in this article correspond to the ones used in the original article in Portuguese.

[1] ADS-B: Vigilância automática dependente por radiodifusão (*Automatic Dependent Surveillance – Broadcast*).

RESUMO

A Vigilância Dependente Automática por Radiodifusão (ADS-B) é uma tecnologia bastante conhecida, padronizada internacionalmente e reconhecida como uma forma barata de se realizar vigilância similar ao radar, inclusive sobre locais onde a vigilância por radar convencional não é adequada. A implementação desta tecnologia significa a introdução de novas configurações de espaço aéreo monitorado e novas capacidades operacionais. A regulamentação do Departamento de Controle do Espaço Aéreo (DECEA) e da Agência Nacional de Aviação Civil (ANAC) deverá prover processos adequados para as operações da aviação civil de forma a fazer frente a esta etapa evolutiva. Este estudo cujo objetivo é contribuir para o fortalecimento da regulação que dará suporte ao ADS-B no Brasil foi desenvolvido com base no método hipotético-dedutivo, subsidiado por revisão bibliográfica, entrevistas não estruturadas do tipo focalizadas, estudos de casos de regulação internacional e estudo de caso de implantação nacional do ADS-B. Resultou na identificação de hipóteses de melhorias regulatórias com impacto positivo à implementação do ADS-B no espaço aéreo nacional, a serem submetidas à verificação e discussão posteriores.

Palavras-chave: *ADS-B. Regulação. Vigilância. Aviação civil.*

1 INTRODUCTION

The implementation of Automatic Dependent Surveillance-Broadcasting (ADS-B) in Brazil demands that the national regulation be improved to accompany this evolutionary stage and provide the necessary conditions for the safe and efficient use of this technology.

Due to this problem, this study aims to identify possibilities for improvements in the Brazilian regulation regarding to the implementation of ADS-B.

Based on the hypothetical-deductive methodology and research techniques such as literature review, unstructured interviews of the focused type, and case studies, such hypotheses for improving regulation were developed.

2 METHODOLOGY

This work was developed based on the hypothetical-deductive method (LAKATOS, MARCONI, 2003), which was supported by several research techniques.

Initially, through literature review, theoretical foundation was sought in order to identify, have a clear purpose of the problem and a viable research proposal.

After that, a non-structured focused interview (LAKATOS, MARCONI, 2003) was conducted with subject matter experts, followed by international benchmarking and a case study on the implementation of ADS-B in the national airspace. This method allowed the advancement of the initial conjectures, leading to the proposed hypotheses for the improvement of the national regulation regarding the use of ADS-B in the national airspace.

It can be observed that in this work, these hypotheses have not been subjected to tests that allow them to be validated and, therefore, it is understood that they would be useful as initial subsidies for the regulatory impact analysis processes of the relevant bodies.

3 LITERATURE REVIEW

3.1 History

The evolution of Data Link Communication (Data Link) for aviation purposes goes back to the 1970s, with the use of the first ACARS applications - "Aircraft Communication Addressing and Recording System". (SPITZER, et al., 2014).

In 1983, the International Civil Aviation Organization (ICAO) established the Special Committee on Future Air Navigation Systems (FANS) to study the use of "Automatic Dependent Surveillance" (ADS) for civil aviation. (SPITZER, et al., 2014).

In 1998, document DO 242 was published by RTCA, in which the Minimum Aviation System Perfomance Standards (MASPS) of ADS-B technology was set, and in 2000, document DO 260 was also published by RTCA, in which the Minimum Operational Performance Standards (MOPS) for 1090 MHz airborne ADS-B equipment was set. (RTCA, 1998, 2000).

Three transmission technologies have been developed and are standardized by ICAO for ADS-B: UAT - Universal Access Transceiver (ICAO Doc. 9861); VDL4 – VHF Digital Link Mode 4 (ICAO Doc. 9816); 1090 MHz ES (ICAO Doc. 9871); however in Recommendation 1/7 of the "AN Conf / 11" in 2003, ADS-B 1090 MHz ES was recommended by the ICAO Council as the international standard to be used. (ICAO, 2012, 2016).

Due to the development of standards, there are three distinct versions of ADS-B in use today based on 1090 MHz ES.

Taking important steps to improve ADS-B evolutionary path, AIREON, an American company established in 2012, in partnership with the company Iridium, hosted its specially designed ADS-B receivers on 66 satellites from Iridium Next Constellation, to provide global ADS-B coverage (AIREON, 2019b, 2020).

3.2 Concepts and definitions relating to ADS-B

In order to establish an international standard for ADS-B concept, in ANNEX 11, ADS-B was defined by ICAO as:

> Automatic Dependent Surveillance-Broadcast (ADS-B). A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link. (ICAO, 2016, p. 1-6).

Taking the possibilities about ADS-B into consideration, it is important to highlight the two distinct concepts: ADS-B OUT, a function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers and ADS-B IN, a function that receives surveillance data from ADS-B OUT data sources. (ICAO, 2014, p. 1-1).

ADS-B OUT requires the implementation of some type of reception capability for practical results, which can be terrestrial, satellite, or ADS-B IN. Furthermore, since the information is originated from the transmitting aircraft, the number of equipped aircraft in the airspace is critical for several ADS-B applications.

The diagram in Figure 1 summarizes the ADS-B system considering the 1090 MHz ES standard.

As common features to all implemented ADS-B 1090MHz ES configurations, it is important to emphasize:

I. Transmitted information

> ADS-B transponders broadcast aircraft parameters, such as identification (24-bit address and flight identification as per the flight plan), position (latitude, longitude and pressure altitude), three-dimensional velocity and position integrity, via a broadcast-mode data link on 1090 MHz. (CANSO, 2016, p. 13).

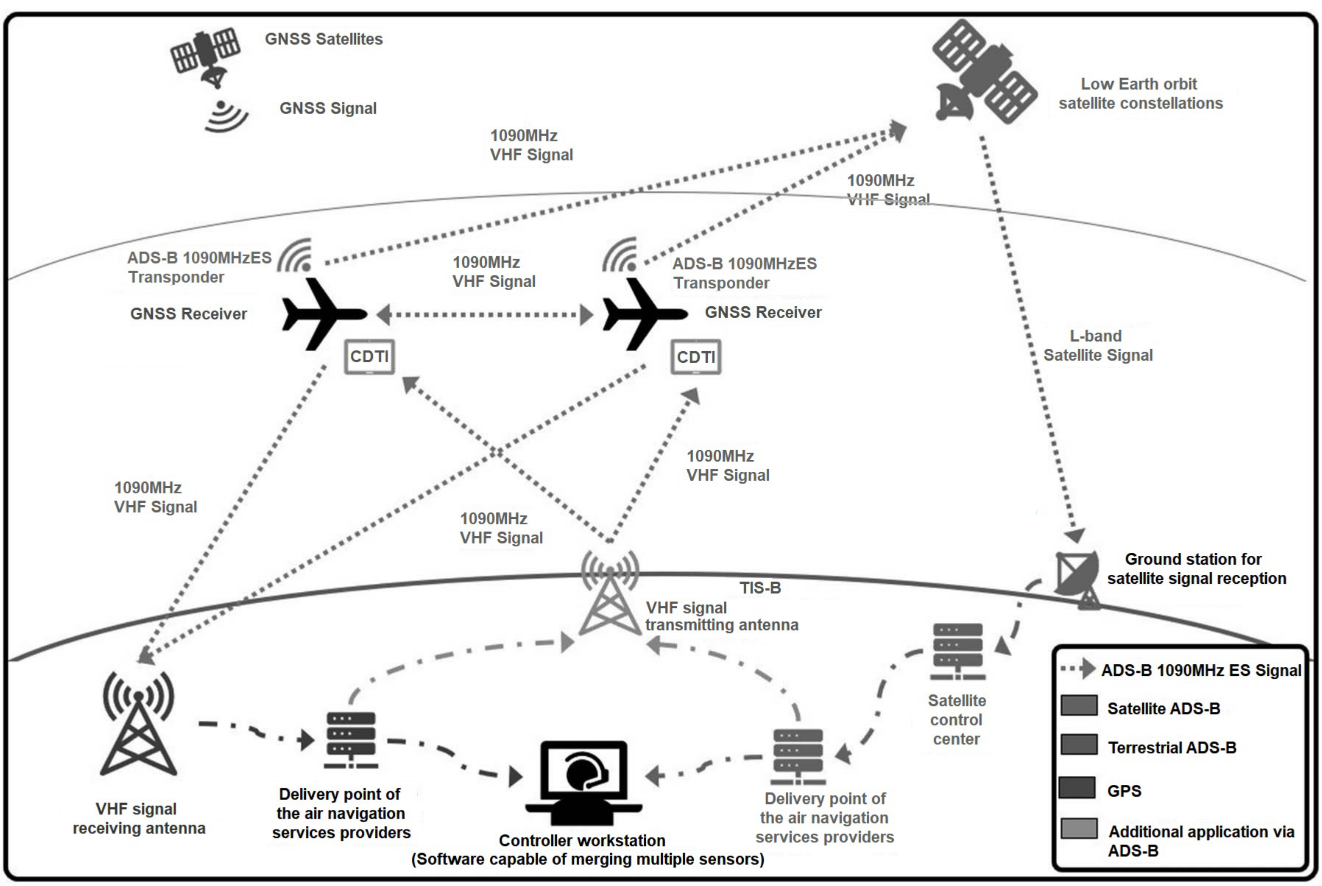
II. Transmission update time

Twice a second, commonly referred to as the ADS-B update rate, is the update rate for the position information. (RTCA, 2000).

III. Minimum avionics requirements:

GNSS system; 1090MHz ES transponder; in a satellite-based ADS-B system: A1 class transmitter and top mount aircraft antenna. (AIREON, 2019b).

Figure 1 - ADS-B system based on 1090MHz ES transponder.



Source: Adapted from AIREON (2019a), RTCA (2002) e CANSO (2016).

IV. Minimum infrastructure requirements:

Simple antenna and receiver connected to communication links that deliver the information to the situation display which shows it in a similar way to radar. (ICAO, 2012).

The satellite-based system requires no ground infrastructure and information is delivered at a specified delivery point. (AIREON, 2019b).

V. Minimum surveillance capabilities

Separation of at least five nautical miles (5 NM), subject to compliance with certain conditions. Extension of surveillance coverage to low altitudes. (ICAO, 2012).

3.3 ADS-B in Latin America

In the multilayer structure of the ICAO Global Air Navigation Plan (GANP), Doc 9750 (ICAO, 2019b), the third layer is the Regional level. In the regional office for Latin America (SAM), the ADS-B implementation strategy foresees coverage of en-route and terminal areas, involving users and service providers, and will be completed by 2023. (ICAO, 2017a).

The results achieved in each contracting State until 2019 are summarized in Figure 2.

Figure 2 - Status of ADS-B implementation in Latin America.

Source: Prepared by the author based on information available in ICAO (2019a).

In addition, a study on the possibility of providing ADS-B via satellite was carried out. The signal was distributed through the existing digital communications network (REDDIG) in the region, and it was concluded that it would be possible in an economical and efficient manner (ICAO, 2018).

In this study, an estimated cost comparison was presented for the different surveillance systems in the region, according to Table 1.

3.4 ADS-B in Brazil

Specifically, with regard to ADS-B implementation in Brazil, a factual result was the establishment of a fully operational airspace restricted only to ADS-B equipped aircraft at TMA Macaé, Bacia de Campos. (ICAO, 2019a).

In 2017, the Brazilian ADS-B implementation plan foresaw low altitude installation in the ocean basins and the establishment of 62 ground stations, RTCA standard DO 260, DO 260A and DO 260B, for continental airspace coverage including homogeneous ATM areas and main air traffic flows. Furthermore, it was planned that this would be done until 2021 and without mandates, divided into 04 phases as it can be seen in Figure 3. (ICAO, 2017a).

However, with the advent of space-based ADS-B, this implementation plan is being revised and the new strategy has not been published yet.

An important step on this issue was the successful integration of satellite ADS-B data into the software used by DECEA in its surveillance routines. (AIREON, 2019a).

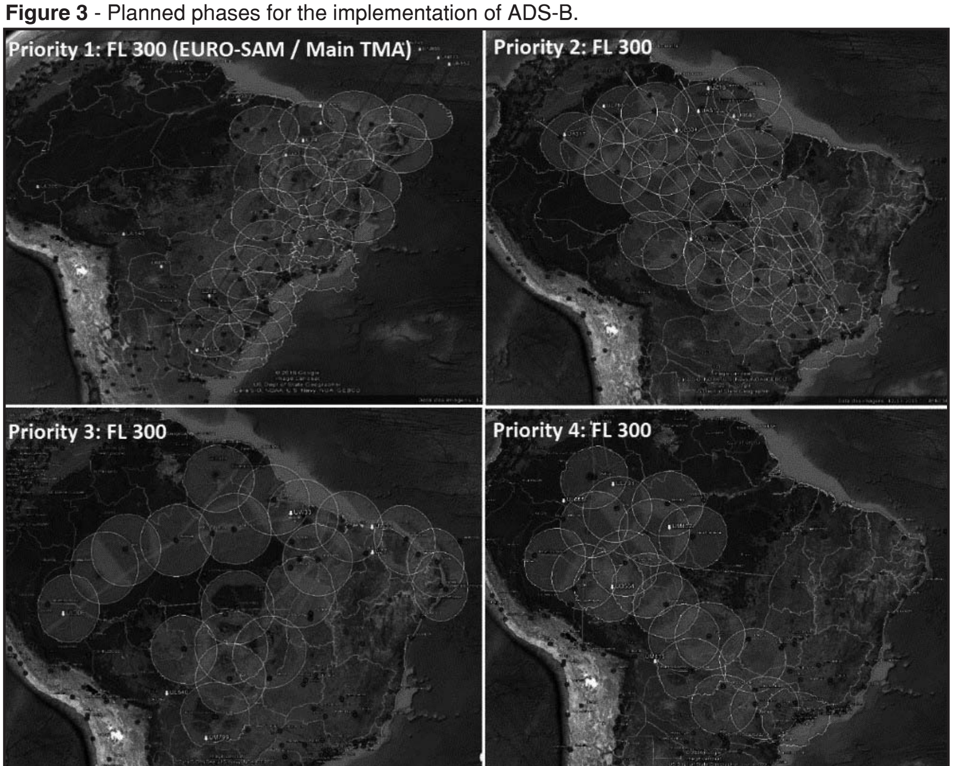
Table 1 - Annual cost comparison of the systems.

	% de coverage		Annual cost / coverage		
	ADS-B Sat.	SSR	ADS-B Sat.	SSR	ADS-B Terr.*
FL 100	100	27,86	0,53	4,25	1,27
FL 150	100	35,01	0,53	3,38	1,01
FL 250	100	46,26	0,53	2,56	0,77

* A fictitious number of ground ADS-B stations was adopted equal to the current SSR facility lease.

Source: ICAO (2018).

Figure 3 - Planned phases for the implementation of ADS-B.



Source: ICAO (2017a).

Additionally, Brazil-AIREON technical cooperation consists of a two-phase plan whose objective is to evaluate the system performance in the Brazilian airspace, analyzing parameters such as: accuracy; latency; update time interval; positioning errors; availability; continuity; and evaluation of different antenna configurations, among others. Although this plan is in its final stages, the results are not available yet (FAGUNDES, 2020).

3.5 Regulation of current ADS-B

The institutional framework of Brazilian civil aviation consists of several institutions with specific roles. In two of these institutions, the definition of civil aviation regulation adopted by DECEA is complemented by the one adopted at ANAC when defining the civil aviation regulation. Regarding ADS-B technology, since DECEA is the Brazilian ANSP and also the ATS regulator, it sets almost all the regulations. However, there is a regulatory interface with ANAC regarding airworthiness and flight standards.

Within the scope of DECEA, ADS-B is mentioned in the following regulations:

- DCA 351-2 National ATM operational design (BRASIL, 2011);
- ICA 100 31 Air traffic service requirements (BRASIL, 2017c);
- ICA 100 37 Air traffic services (BRASIL, 2019b);
- CIRCEA 121-7 Automatic Dependent Surveillance-Broadcast (ADS-B) Flight Inspection (BRASIL, 2017a);
- MCA 64-3 Aeronautical search and rescue coordination manual (BRASIL, 2019a);
- MCA 100-11 Completion of flight plan forms (BRASIL, 2017b);
- AIC 40-17 Automatic Dependent Surveillance-Broadcast (ADS-B) in TMA Macaé (BRASIL, 2018b);
- AIC 47-18 Airspace restructuring of Macaé Terminal Control Area (TMA) with ADS-B sensor application, increase of VHF coverage, implementation of ADS-B exclusive airspace concept and provision of meteorological products from EMS-A (BRASIL, 2018a).

Within the scope of ANAC, ADS-B is directly mentioned only in document IS 21-013 B "Instructions for obtaining approval for GNSS (Global Navigation Satellite Systems) stand alone equipment installation for VFR and IFR operations" (BRASIL, 2016).

The basic structure for operational standard regulation at ANAC is established by the document RBAC 091 - "General Operating Requirements for Civil Aircraft" (Brasil, 2019c), which is on a par with the provisions in the North American standard "Code of Federal Regulations – CFR, Title 14, Chapter I, Subchapter F, part 91", called "General Operating and Flight Rules", the standard in which the ADS-B mandatory requirements were defined, in items 91.225 and 91.227. (ESTADOS UNIDOS, 2020).

However, according to the Brazilian standard, the items marked as "Reserved" and no requirements have been defined. On the other hand, in requirement 91.215 an instruction that enables the use is established, but it does not define a specific standard:

> 91.215 (b) When the type of operation and/or airspace requires, the aircraft shall be equipped with a transponder, with OTP approval (TSO), maintained in accordance with section 91.413 of this Regulation.

4 PROBLEM ANALYSIS AND IDENTIFICATION

The analysis of the existing regulation resulted in the identification of gaps or issues not addressed by the current regulatory framework. These gaps or issues may be improved in order to support the implementation of ADS-B in the national airspace:

- New types of airspace with surveillance: Today, there is only one type of ATS surveillance in the Brazilian continental airspace, which is radar-based.
- Transponder standard and restriction to other types: The regulation is not clear about the model that is required in the Brazilian ADS-B airspace. It is also not mentioned how other equipped types of aircraft should operate when entering the Brazilian ADS-B airspace.
- Expected capabilities and corresponding requirements and limitations: It is not clear what ADS-B applications are expected, the corresponding requirements, system performance limitations and the airborne equipment.
- Equipped fleet: There is no continuous effort to achieve a higher level of ADS-B equipment in the fleet and this is a problem for many applications.
- Specific goals for ADS-B implementation: Safety and capacity gains are associated with the implementation of ADS-B near airfields or helipads and even monitoring ground movement.

- Airport concession contracts as an opportunity: Throughout the subsequent rounds of concessions carried out by the Brazilian Federal Government, the contracts have evolved. Since the contracts seek to increase airport safety and capacity, it would be an opportunity to introduce the mandatory installation of ADS-B at the airport.
- Satellite ADS-B or Terrestrial ADS-B l: Satellite ADS-B is expected to achieve better performance than the radar, although worse than Terrestrial ADS-B in most cases, if the appropriate infrastructure is provided.

5 EXPERT OPINION

This study was carried out through a non-structured focused interview (LAKATOS, MARCONI, 2003). Seven specialists, who occupy strategic positions, have expertise on the subject and experience in the implementation of technologies for the management of the national airspace were selected: 1 from INFRAERO, 2 from private companies, 2 from DECEA and 2 from ANAC. Comments about the problem were organized and consolidated in the summarized text, as follows:

- New types of airspace with surveillance: the system should automatically identify the best signal in each phase of the flight and provide information to the controller and the crew in a homogeneous way. Such information must be clear regarding the use of sensors, providing new features and benefits. DECEA technical staff will need training, and DECEA and ANAC new rules will be required.
- Transponder standard and restriction to other types: ES 1090MHz (0, 1 or 2) used at Bacia de Campos may be the standard, since DECEA is already using it and it is an international standard. More systems add complexity to the implementation. There is no planned limit to the signal quality parameters.
- Expected capabilities and corresponding requirements and limitations: The implementation should seek cost efficiency. The radar could be disabled after implementation where the radar coverage is already provided. Primary radars are a sovereignty concern and should not be disabled. It will be a better precision surveillance with better update time rates. It provides surveillance service to the user, including low altitude in oceanic airspaces. There are no plans for TIS-B, FIS-B, ADS-R or monitoring tools.
- Equipped fleet: Airlines should be equipped since new aircraft already have the new system, besides international mandates, which require the use of this new equipment. Problems can be faced by the Air Cargo companies due to the fleet, which is old. Equipping the aircraft will be optional. However, the companies which is better equipped will use the system. Currently there is no information about the percentage of the fleet which is equipped. Users are expected to recognize the system, for it will define the future of the airlines. There are no planned mandates, although, probably, it will be soon a necessary demand.
- Specific goals for ADS-B implementation: Surveillance extended to coverage for low altitudes in ocean basins, where off-shore movement is intense, is a specific goal to be achieved. For the airport surface, the use of ADS-B signal would be another option. DECEA is guided by operational needs which will shape the system.
- Airport concession contracts as an opportunity: Usually, air traffic management infrastructure is not part of a concession agreement, and for specific cases it would probably be beneficial to include DECEA in the initial consultation processes. There are possible airport uses, such as SMGCS, but it is up to the airport manager to decide whether to implement it. ICA 63-18 is defined by DECEA.
- ADS-B Satellite or ADS-B Terrestrial: A combination is considered the ideal solution. There are specific situations where you can benefit from each type. The conditions that will define the extent of the use of one or the other depend on the result of the tests that are still in progress. Installation feasibility, signal quality, redundancy, and security justify the use of both systems. The current ADS-B deployment plan considers Terrestrial ADS-B with strategically placed sensors to provide surveillance services above FL245, the TMA airspace volumes and down to the ocean basins over Santos / Espírito Santo / Campos (already deployed). Satellite-based ADS-B testing is ongoing, in a controlled environment, where space-based

and radar data can be integrated and the results compared. It is known that the latency parameter was worse than expected due to the network which was used.

6 INTERNATIONAL REGULATORY CASE STUDIES

Three States were selected as a sample of international regulation on ADS-B and their main aspects are summarized in Table 2 and Figure 4.

A reference case regarding the possibilities of the system, the United States of America (USA), carried out a robust deployment, with 650 antennas, total coverage of airspace, 02 types of transponder in use, additional services such as TIS-B, FIS-B, and ADS-R, and a mandate that has been in effect since January 2020 covering all users, including General Aviation. The United States (2020) and the United States (2015, 2018, 2019).

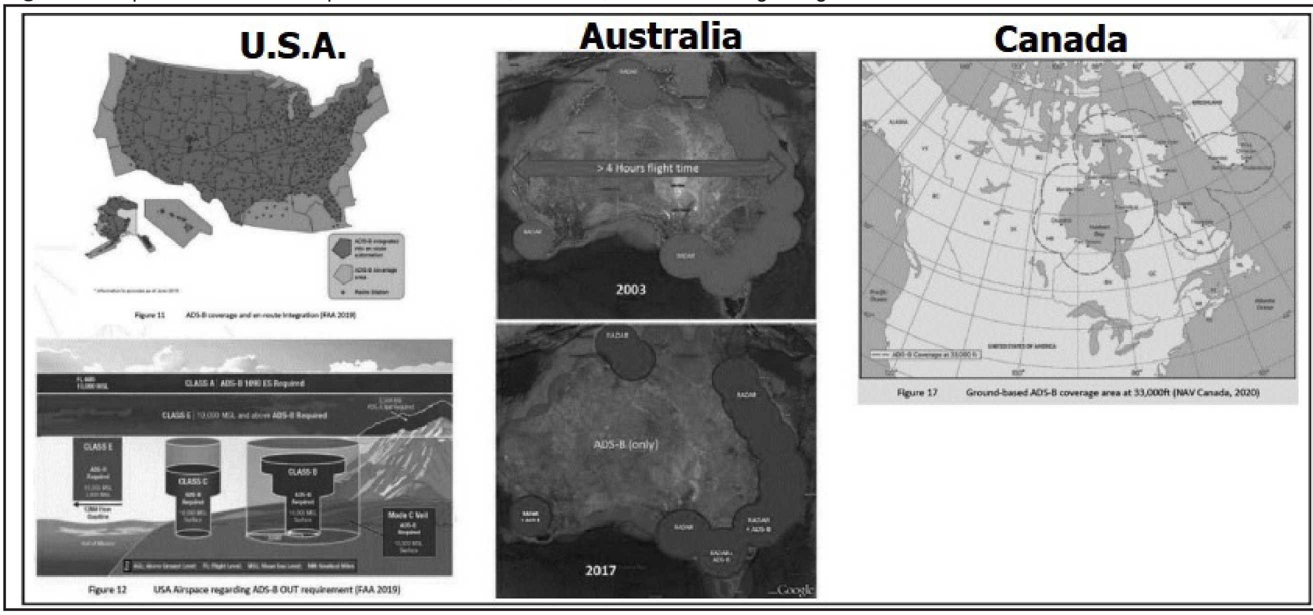
Australia has also been using ADS-B throughout its airspace as primary surveillance system since 2009 standing out for the optimization of communication, navigation and surveillance systems achieved through the use of ADS-B. Such deployment was optimized by using about 70 antennas, full airspace coverage, and 01 type of transponder in use. It made it possible to deactivate 179 aids to navigation. Australia has also defined specific regional issues in ICAO DOC 7030 in relation to ADS-B and has mandates for commercial aviation, but not for General Aviation. Australia (2015, 2020a, 2020b); ICAO (2017b).

Table 2 - Case studies of international regulation - summary table.

Aspect	U.S.A.	Australia	Canada
ADS-B Use	Primary surveillance system	Primary surveillance system	Primary surveillance system (where available)
Coverage	Entire country	Entire country	Northern airspace * (*nationwide plan)
Infrastructure (ground stations)	650	70	15
Additional ADS-B services	TIS-B; FIS-B; ADS-R; Monitoring system	None	None
Advanced ADS-B Applications	CAVS; ITP; IM	None	None
Type of Transponder	1090 MHz ES 2 UAT 978MHz	1090 MHz ES 0,1 or 2	1090 MHz ES
Main regulations	14 CFR § 91.225; 14 CFR § 91.227; AC 90 114 B; AC 20 165 B; SRT 47 Rev.4; TSO C166b; TSO C154c	CAO 20.18; AC 21-45; AC 91-23;	AC 700 009 e;
Mandate to equip the fleet	Yes	Yes	No
Mandate includes general aviation	Yes	No	-
Mandate includes foreigners	Yes	Yes	-

Source: Elaborated by the author from the document information United States (2015, 2018, 2020), Australia (2015, 2020a, 2020b), NAVCanada (2020) and ICAO (2017b).

Figure 4 - Representations of Airspace from the USA, Australia, and Canada regarding ADS-B.



Source: Elaborated by the author adapted from ICAO (2017b).

Finally, due to the size of its airspace and pioneering use of the satellite solution which is a possibility for Brazil and also with a vast airspace, Canada has used ADS-B since 2010 in the northeastern airspace, with one type of transponder and has no defined mandate. It is pioneering in the use of satellite ADS-B, which is being tested in the whole country. NAVCanada (2020), Canada (2011, 2018) e ICAO (2017b).

7 CASE STUDY TMA ME

This is the first case of ADS-B system deployment in Brazilian airspace. It was a project carried out from 2009 to 2018.

It has achieved important results and corresponding benefits:

- IFR x IFR separation for aircraft under surveillance: 5NM (AIC 40/17);
- Delays reduced by 43% / Flight punctuality increased by 16%;
- More effective search and rescue (SAR);
- Flight time reduction with estimated fuel savings of up to R$1.31 million per year; and
- 122 equipped helicopters (CANSO, 2019).

The initial and the post implementation scenario can be seen in Figure 5.

Figure 5 - Main aspects of the ADS-B implementation case scenario at TMA ME.

TMA ME		
Aspect	**Before**	**After**
Infrastructure	APP-Macaé: PSR / SSR Radar; 03 *offshore* radios	APP-Macaé: PSR Radar / SSR radar; 06 ADS-B antennas: 02 onshore/ 04 *offshore*.
Coverage	Sector 1: Radar; Sector 2: Conventional surveillance; From 2.000' to FL 145.	Sector 1 and 2: Fusion ADS-B + Radar; Sector 3 to 8: ADS-B (sep. 5NM) From the surface to FL 145.

Source: Elaborated by the author from data extracted from Brazil (2018a, 2018b), ICAO (2018a) and INFRAERO (2019a, 2019b)

8 PROPOSALS FOR REGULATION IMPROVEMENT

Consolidating the information obtained in the review, in the interviews, in the international regulation case studies, in the Terminal ME case study, and considering the implementation conditions in Brazil, in order to address the subjects of the problem of regulation improvement to subsidize the implementation of ADS-B in the national airspace, the hypotheses identified were proposed in Table 3.

Table 3 - Proposals for ADS-B regulatory improvement.

Description	Motivation	Main expected benefits
Problem: New types of airspace with surveillance		
Proposal: ADS-B required above FL290 and in oceanic airspace		
Establish a requirement that the aircraft be equipped when above FL290 and in oceanic airspace.	• Set a clear rule to require the equipment ADS-B for operational safety; • Reduce effort for implementation: better equipped aircraft move in RVSM airspace (above FL290); Traffic off-shore has the ability to promote ADS-B installation on aircraft; • Provide conditions for new features and benefits inherent to the ADS-B system.	• Minimize interference from non-equipped aircraft in airspace where ADS-B services are provided; • Provide ADS-B services in a portion of the Brazilian airspace, with 100% of the user aircraft equipped;
Proposal: ADS-B specific document		
Prepare a specific document containing all aspects of flight standards and airworthiness relating to ADS-B foreseen for use in the national airspace.	• Promote system compliance; • Facilitate the training of users and controllers.	• Improving operational safety through knowledge.
Problem: Standard transponder and restriction to other types		
Proposal: Standard for ADS-B transponder and zero bad signals		
Set 1090MHz ES 0,1 or 2 as the Brazilian standard and require that other standards can't transmit.	• Minimize occurrences of aircraft with non-compliant equipment; • Optimize system complexity; • Provide a business vector for the industry responsible for equipping the aircraft; • Ban inappropriate signals for the national ADS-B.	• Alignment with internationally recognized standard; • Gain in the availability of ADS-B equipment in the fleet.
Proposal: Minimum quality of the transmitted signal		
Set limits for the quality parameters that are part of the transmitted signal: NUC, NIC, NAC, SIL.	Ensure the minimum expected system conditions for the intended surveillance functions.	Improved safety and basic conditions for ADS-B applications.
Proposal: Compliant and operational transponder is required to transmit		
Establish a requirement that properly equipped aircraft transmit the ADS-B signal throughout the flight.	• Maximize the signal quality available in ADS-B airspaces; • Establish condition for repress actions against unsafe conduct when in ADS-B airspace.	Reduce risks of aircraft in flight going undetected, contributing to improved operational safety.

Source: The author.

Table 3 - Proposals for ADS-B regulatory improvement (continued).

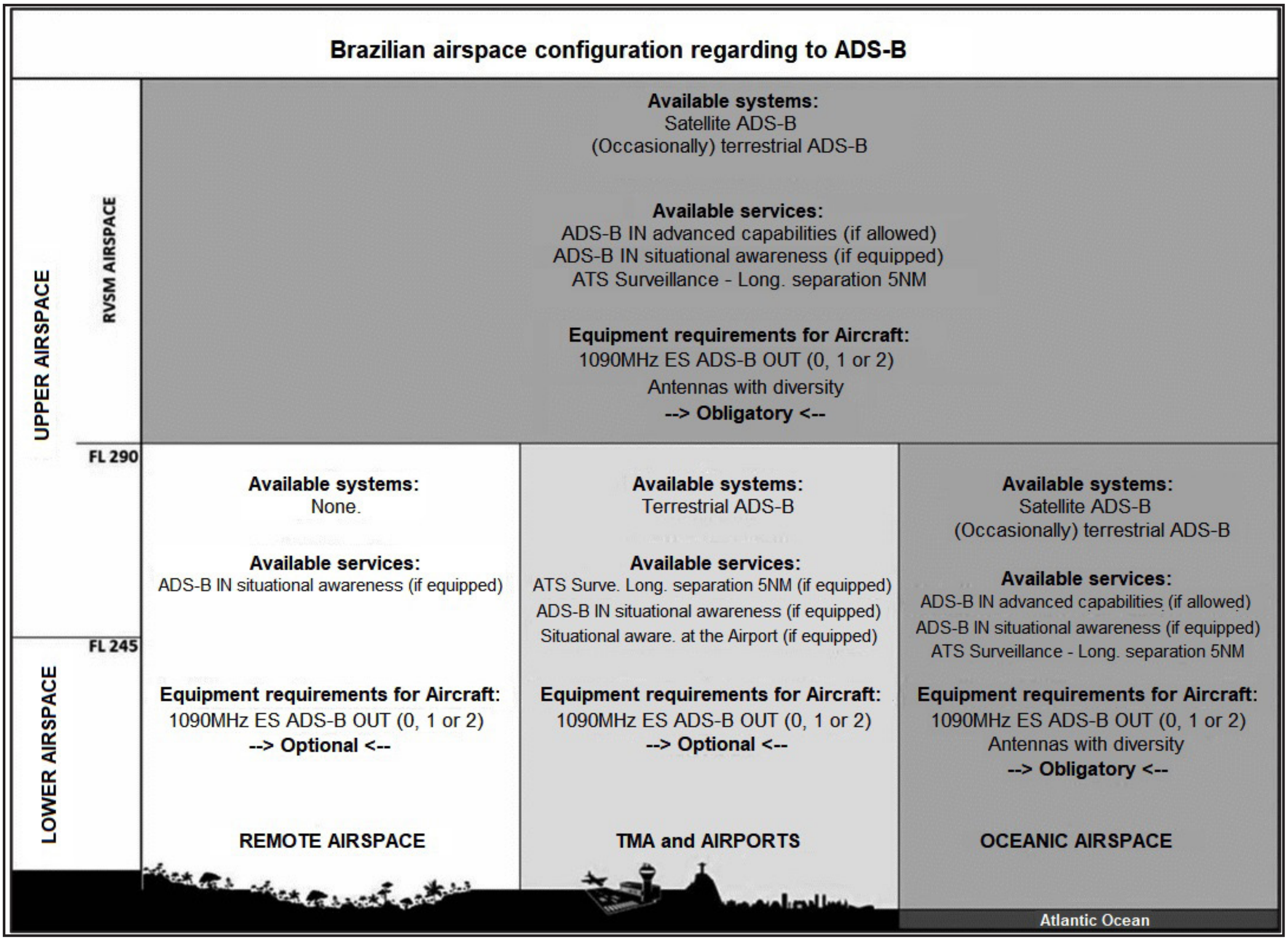
Proposal: Procedure for non-compliant, non-operational transponder and exceptions		
Establish procedures for handling specific cases concerning flights without the appropriate ADS-B transmission.	• Ensure flight conditions for aircraft that are not properly equipped; • Ensure flight conditions for aircraft that for reasons deemed valid, cannot transmit the signal.	• Solve the exceptions and allow the flights safely.
Problem: Expected capabilities and corresponding requirements and limitations		
Proposal: Authorization required for advanced applications of ADS-B IN		
Establish requirement to obtain prior authorization for the use of advanced ADS-B IN applications.	• Make sure that advanced ADS-B IN maneuvers are performed with the proper equipment and trained aircrew.	• To provide conditions for the safe performance of advanced ADS-B IN maneuvers in Brazilian airspace.
Proposal: Statement that there are no complementary ADS-B services		
Document specific provision to inform airspace users that there are no services such as TIS-B; FIS-B; ADS-R.	• Avoid confusion with capacities available in other countries.	• Safety improvement.
Problem: Equipped fleet		
Proposal: Monitoring the availability of ADS-B in the aircraft fleet		
Implement routine to monitor the installation of ADS-B 1090MHz ES transponder on aircraft using the national airspace.	• Provide information for planning the deployment of ADS-B and implementing policies regarding its use; • Seek to achieve the necessary conditions to implement ADS-B applications that require 100% of of the aircraft equipped and transmitting.	• Informational asset for the entire industry.
Problem: Specific goals for ADS-B implementation		
Proposal: Infrastructure deactivation as part of the plan		
In deployment planning, consider optimizing resources by deactivating radar stations and other aids where possible.	• Minimize the emission of radio signals in the 1090MHz frequency and ensure capacity for the systems; • Reduce the operational cost of communication, navigation and airspace surveillance systems as a whole; • Increase the efficiency of communication, navigation, and surveillance services.	• Optimization of communication, navigation, and surveillance systems.

Table 3 - Proposals for ADS-B regulatory improvement (continued).

Proposal: Database and monitoring tools		
When configuring the system, consider implementing resources for collecting and storing in a structured way the data from ADS-B.	• Promote knowledge and learning from operational data.	• To provide data for the analysis and improvement of national aviation.
Problem: Airport concession contracts as an opportunity		
Proposal: ADS-B in airport concession contracts		
In implementing the system, consider the possibility that the installation, commissioning, and maintenance of ADS-B near major airports be assigned to the private sector through the airport concession contract.	• Assign costs to the benefiting entity for the results of the system, since providing ground ADS-B will bring operational benefits to the airport; • Reduce the effort to implement the system, through private investments, which mitigate problems inherent to obtaining public resources; • Expand the resources employed in the concession contracts to seek improvements in operational safety and increase airport capacity.	• Faster installation of terrestrial ADS-B; • Benefits for airport surface surveillance due to ADS-B signal reception capability.
Problem: ADS-B Satellite or ADS-B Terrestrial		
Proposal: Combination of ADS-B terrestrial and ADS-B satellite		
In the system configuration, considerdeploying Satellite ADS-B in all oceanic and mainland airspace above FL 290 and land-based in 52 airports (airports with more than 200,000 pax/year).	• Reduce the effort for implementation, since satellite ADS-B doesn't require infrastructure and ground infrastructure could utilize locations near major airports; • Ensuring high quality of the received signal in the busiest locations.	• Lower operating costs; • Better coverage; • New capabilities; • Integrated information.

Source: The author.

Figure 6 - Profile of the Brazilian airspace with respect to ADS-B.



Source: The author.

9 CONCLUSION

ADS-B is a technology that offers extended surveillance coverage, radar-type separation, better update time than radar, enhanced application possibilities, and is a foundation for future uses that are being developed, all at a substantially lower cost.

Considering that the implementation is underway and will be completed soon, it is necessary to improve the regulation, encompassing, in a way, all aspects related to civil aviation to ensure the safe and efficient use of technology in Brazilian airspace.

In this study, important aspects have been identified as regulatory improvements and, in a subsequent step, it is expected that these improvements can be good inputs for discussions in the appropriate forums.

10 ACRONYMS

ADS-B - Automatic Dependent Broadcast-Surveillance;
ADS-R - *Automatic Dependent Surveillance-Rebroadcast;*
ATM - *Air Traffic Management;*
FIS-B - *Flight Information Service - Broadcast;*
FL - *Flight Level;*
GNSS - *Global Navigation Satelite System;*
NAC - *Navigation Accuracy Category;*
NIC - *Navigation Integrity Category;*
NUC - *Navigation Uncertainty Category;*
PSR - *Primary Surveillance Radar;*
RVSM - *Reduced Vertical Separation Minima;*
SIL - *Source Integrity Level;*
SMGCS - S*urface Movement Guidance and Control System;*
SSR - *Secondary Surveillance Radar;*
TIS-B - *Traffic Information Service - Broadcast.*

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