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# The Certification Challenge of Integrated Avionics and Air Traffic Management Systems

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## Abstract

Aviation must undertake considerable modernisation efforts in an era of steady air traffic growth to meet the crucial challenges faced by the industry, which include increasing demand for capacity and efficiency, stronger focus on global aviation safety and greater concerns on minimising adverse effects on the environment. Regulation and certification are vital to ensure high levels of safety and should also evolve harmoniously with the technological developments of Next Generation Avionics and Air Traffic Management (ATM) systems.

This paper presents the challenges and opportunities for the evolution of the certification framework, considering the Global Air Navigation Plan (GANP) of International Civil Aviation Organisation (ICAO) and major air transport modernisation programs including, inter alia, the Single European Sky Air Traffic Management Research (SESAR) of Europe, Next Generation Air Transport System (NextGen) of the United States and OneSky of Australia. A critical review is carried out on the existing regulatory frameworks of the concerned aviation authorities namely the European Aviation Safety Agency (EASA), the Federal Aviation Administrator (FAA), the Civil Aviation Safety Authority (CASA) and the ICAO in relation to certification, in order to identify the key areas requiring further developments. Furthermore, a review of current industry standards in relation to hardware and software design, development, test & evaluation together with available standards for safety assessment are also presented, highlighting the outstanding gaps which should be fulfilled to achieve an integrated Communication, Navigation, Surveillance/Air Traffic Management (CNS/ATM) system certification. The paper then proposes a top level framework for integrated CNS/ATM system certification considering airborne as well as non-airborne systems, together with a matrix for means of compliance.

Keywords: Certification, Safety, Airworthiness, Air Traffic Management, Avionics, CNS/ATM

# 1. Introduction

Aviation is undergoing significant evolutions, with many technological developments taking place in the domains of Communication, Navigation and Surveillance (CNS) using novel Avionics and Air Traffic Management (ATM) applications. With air traffic doubling its size every fifteen years, demand for air space capacity, aviation safety, security and efficiency is continuously increasing, whilst the need to minimize adverse effects on the environment due to fuel burn and gaseous emissions, is also crucial for sustainability. In this context, the Single European ATM Research (SESAR) is a collaborative industrial/academic/government effort towards ATM modernisation in Europe (Ky and Miaillier, 2006). A similar research program in the United States is Next Generation Air Transport System (NextGen) which is led by the Federal Aviation Administration (FAA) (Sueki and Kim, 2016). Many other regional programs are under way including OneSky in Australia, Collaborative Action for Renovation of Air Traffic Systems (CARATS) in Japan, SIRIUS in Brazil and other similar programs in Canada, China, India, and Russia (ICAO, 2013c). The Global Air Navigation Plan (GANP) developed by the International Civil Aviation Organisation (ICAO) introduces the Aviation System Block Upgrade (ASBU), which harmonises the regional modernisation programs.

Due to its safety critical nature, aviation is a highly regulated industry, with aircraft design, manufacture and operation governed by stringent regulations. Airworthiness certification of aircraft is a well-established mechanism to ensure a minimum level of safety, standardisation and compliance with aviation regulations. Growing concerns in the industry due to terrorism (including cyber terrorism), has resulted in security also being recently included as a certification requirement to ensure protection of the aircraft from unlawful interferences. In addition to safety and security, other driving factors including integrity and interoperability of systems should also be considered in the certification process, which are currently not captured adequately. Reliability, availability and maintainability are also key design drivers already in place, which could be better captured in the certification process, ultimately delivering various benefits to aircraft operators and system manufacturers. Human factors is another important consideration for system certification, with a stronger focus required in the future owing to the extensive technological developments taking place in the Communication, Navigation, Surveillance and Avionics (CNS+A) domain.

Unmanned Aircraft Systems (UAS), also known as Remotely Piloted Aircraft Systems (RPAS) is a rapidly growing industry due to their unique benefits and wide range of possible applications. Certification of RPAS, integrating adequate sense and avoid system functionalities that are required to replicate the see and avoid capability of manned aircraft involves some challenges that must be overcome prior to introduction of RPAS into non-segregated airspace (Ramasamy and Sabatini, 2015b).

In addition to the certification challenges of the airborne systems outlined above, next generation ATM systems and technologies that are being developed as part of the major modernisation initiatives worldwide will be functionally integrated between airborne and non-airborne systems, which places greater demands on the certification process of non-airborne systems. The highly complex and interconnected nature, together with the growing demands for global harmonisation and interoperability for a seamless operation in all phases of flight will have to be properly addressed through evolutions in system certification. Although historically aviation ground systems did not require certification compliance to interface with airborne systems, this is being challenged in an era of ATM modernisation (Kölle et al., 2011). The term “groundworthiness” is used by Kölle et al, drawing a parallel to the concept of “airworthiness” used for airborne aircraft, referring in particular to the safety certification of ground systems supporting airworthy airborne systems. This highlights the requirement of establishing a process, which assures that the ground systems are designed, developed and operated in a reliable, safe and secure manner in order to provide the services to aircraft in flight in the form of Air Navigation Services or Aeronautical Service Information Provision (ASIP).

In the above context, the purpose of this paper is to review the current regulatory framework for the certification of airborne and ground based systems of CNS/ATM to assess its suitability in view of the planned technological developments. The review includes the standards and recommended practices published by ICAO together with related documents. It further reviews regulations and implementing rules of the concerned aviation authorities of the countries of the main modernisation projects namely European Aviation Safety Agency (EASA), FAA, and Civil Aviation Safety Authority (CASA), in relation to certification. It also reviews current industry standards which provide acceptable methods to comply with certification requirements. Further to the said review, we present and discuss a new unified certification framework taking into consideration the integrated and interconnected nature of the airborne and ground based systems, identifying requirements to assure safety, security, integrity and interoperability of the CNS/ATM systems.

The paper is organised as follows. In section 2, we provide an overview of the CNS/ATM concept and its technological roadmap. Then in section 3, we present the review the current regulatory framework identifying gaps that must be fulfilled to fully implement next generation CNS/ATM whilst ensuring safety and security. Section 4 presents a new unified framework for integrated CNS/ATM certification, and section 5 provides the conclusions and future research.

# 2. An overview of CNS/ATM

## 2.1 CNS/ATM concept

CNS/ATM is a revolutionary shift from legacy ATM services, where technological solutions are introduced to exploit the Communication, Navigation and Surveillance systems' performance levels and capabilities.

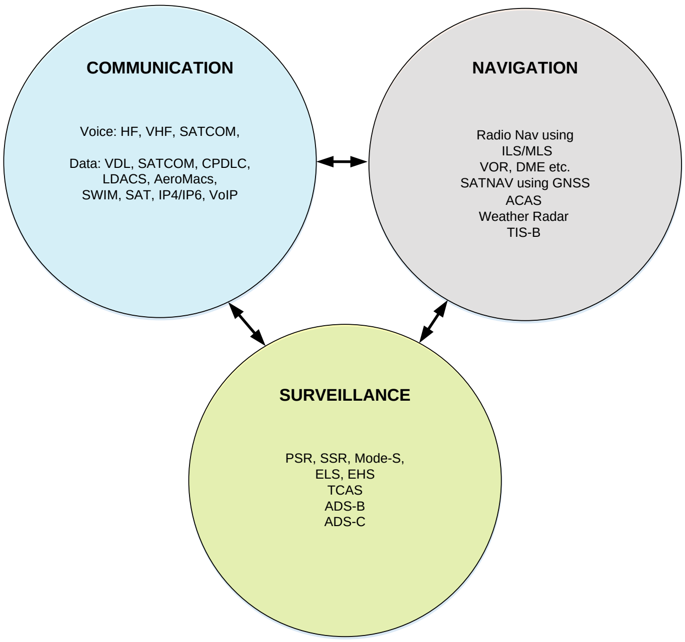
Communication is still largely based on voice interactions between the flight crew and the ATM operators, but considerable efforts are currently underway to expand the use of safe and secure data communication, with increased use of Controller Pilot Data Link Communication (CPDLC), and anticipated introduction of a digital voice system in the future. Data-link communication is also becoming an essential element in evolutionary navigation and surveillance technologies. Furthermore, data-link communication systems will be the backbone of the System Wide Information Management (SWIM) concept of SESAR and NextGen, supporting the ever-increasing information sharing requirements.

Navigation of aircraft, which historically relied on ground based radio navigational aids (nav-aids), is now rapidly evolving towards satellite based navigation systems also known as Global Navigation Satellite System (GNSS) (Sabatini et al., 2013a, Sabatini et al., 2013b), overcoming limitations in range and altitude, disruptions associated with outages and high maintenance costs that are often prohibitive for smaller regional airports, while enhancing accuracy and route flexibility.

Surveillance by ground air traffic service for conflict resolution, sequencing and spacing purposes and also by aircraft for self-separation and collision avoidance, will increasingly involve Automatic Dependent Surveillance (ADS) systems, which in addition to reducing the need for expensive primary and secondary surveillance radar (PSR/SSR), considerably increases the amount of aircraft state and trajectory information exchanged, supporting higher traffic densities.

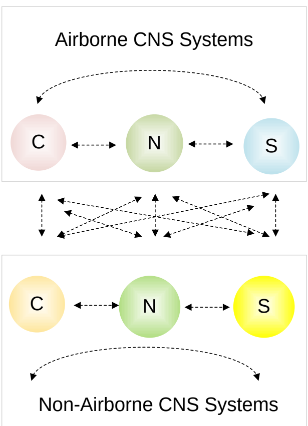
The systems and technologies used for C, N and S are inter-related as illustrated in Figure 1. "Communication" plays an increasingly important role in the CNS concept by providing the vital link not only for typical communication purposes, but also for both navigation and surveillance applications.

Figure 1: Technological interactions of the CNS concept




Within the aircraft systems, the communication, navigation and surveillance systems are integrated and interconnected. For example aircraft positions determined by the aircraft navigation systems are transmitted for surveillance purposes such as to the ADS-B systems. Furthermore, there is a strong interconnection between airborne C, N, S systems with ground systems as depicted in Figure 2. While voice and data link communications are obvious connections between airborne and non-airborne systems, navigation and surveillance systems are also interconnected and integrated. Taking the example of the ADS-B system, the ground-systems rely on the transmission of the aircraft ADS-B Out signals for cooperative surveillance. The signal transmission from conventional ground based navigational aids, and more modern systems such as Ground Based Augmentation Systems (GBAS) of GNSS assist the aircraft in its navigation function. With future 4 dimensional trajectory operations, the airborne Flight Management System (FMS) would be interfacing and communicating with ground ATM systems via datalink communication. Hence the interdependencies of the systems call for an integrated certification framework for CNS/ATM. At present airborne systems are certified through a strong regulatory framework, while system (hardware and software) certification for the non-airborne systems is yet to be fully developed. A comprehensive certification framework should encapsulate the integrated, interconnected and interdependent nature of the airborne and non-airborne systems of CNS/ATM.

Figure 2: The integration of airborne and non-airborne CNS systems

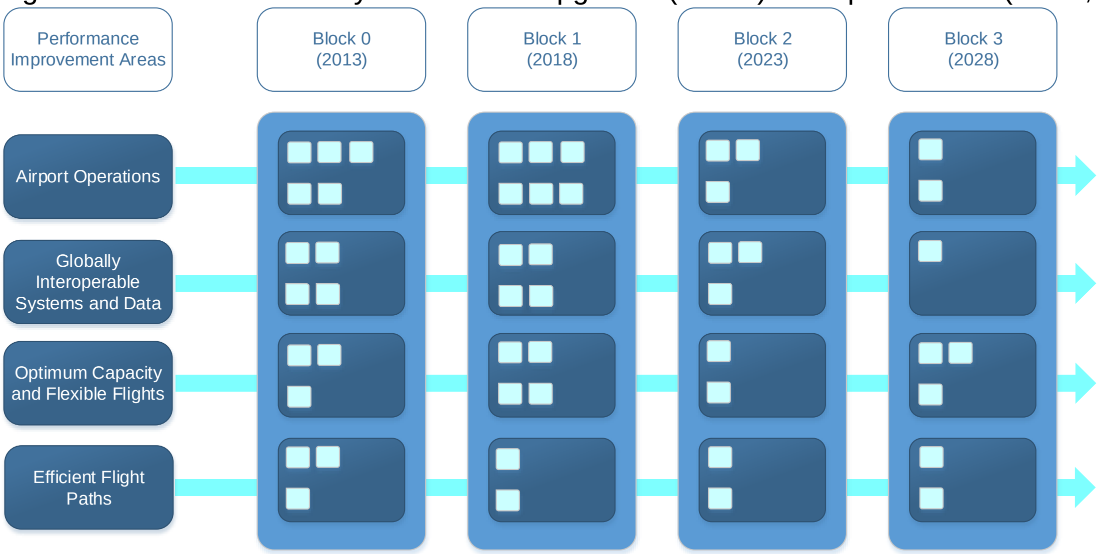


## 2.2 Technological roadmap

The ASBU developed by ICAO, is the deployment roadmap of the GANP and harmonises the efforts of SESAR, NextGen and other programs using a consensus driven systems engineering strategy. As illustrated in Figure 3, the ASBU consists of several blocks, each block spanning a period of five years, and composed of modules which are a collection of technologies and procedures required for each of the four main performance improvement areas, namely (ICAO, 2013c)

- Airport operations,
- Globally interoperable systems and data,
- Optimum capacity and flexible flights, and
- Efficient flight paths.

Figure 3: The Aviation system block upgrade (ASBU). Adapted from (ICAO, 2013c)




In Figure 3, each block upgrade is represented by a blue column. The required technologies and procedures for each block are grouped into “modules” which are shown by the smaller white squares within each block. The modules have been determined in reference to the specific Performance Improvement Areas. The reader is invited to refer to ICAO Document 9750 (ICAO, 2013c) which fully describes the ASBU concept of ICAO’s GANP.

Performance Based Navigation (PBN) is considered as a high priority for air navigation in the GANP, in addition to the Continuous Descent and Continuous Climb Operations (CDO and CCO), Air Traffic Flow Management/ Collaborative Decision Making (ATFM/CDM) and enhanced runway sequencing functionalities.

As part of the evolutionary roadmap of CNS+A, the concept of Performance Based Operations (PBO) requires modern avionics to fulfil Required Navigation Performance (RNP), Required Communication and Surveillance Performance (RCSP) thus fulfilling Required Total System Performance (RTSP). These are minimum performance standards for avionics equipment and procedures, designed to address any constraints in achieving PBO in support of efficient separation between aircraft, and optimal collision avoidance that allow aircraft to fly user-preferred optimal flight paths or User Preferred Routes (UPR). This limits air traffic controllers’ intervention to that required only for high level and emergency decision making.

For global harmonization and interoperability into the future, the required performance levels of avionics systems should be standardized for each airspace. The certification of avionics systems would then be in accordance to established standards.

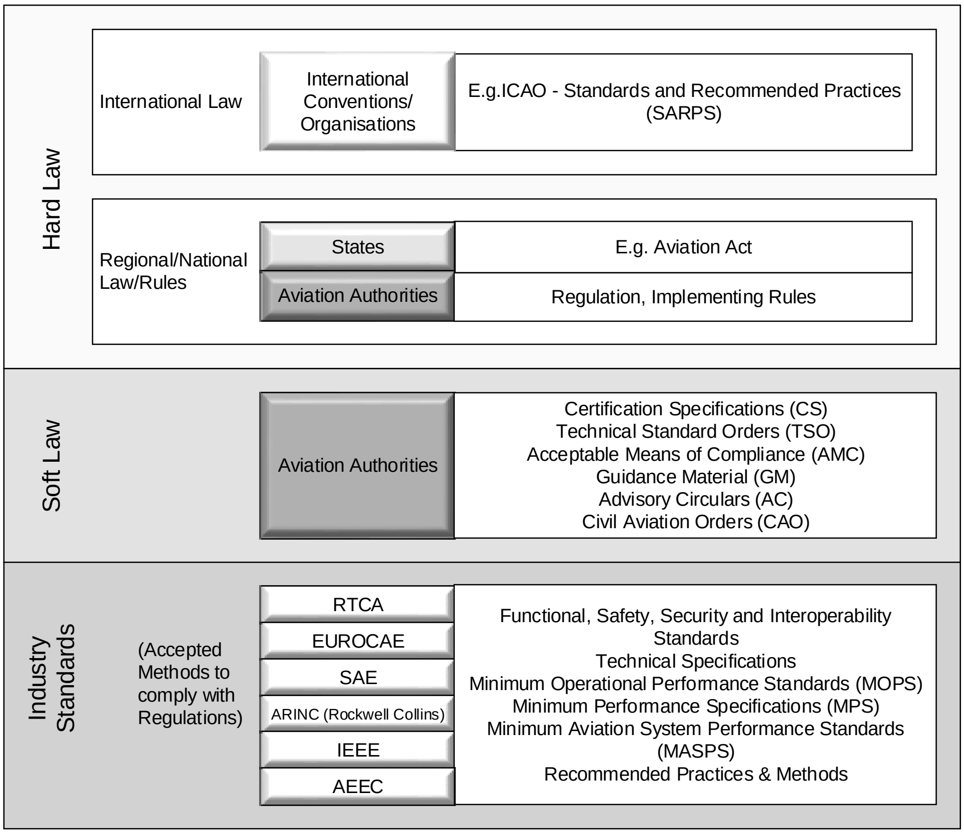
A novel concept of CNS/ATM is Trajectory Based Operations (TBO) which makes use of 4-Dimensional (4D) trajectory management functionalities to promote optimal spacing, Demand/Capacity Balancing (DCB) as well as enhanced rerouting and de-conflicting capabilities. 4D Trajectories (4DT) specify aircraft position in four dimensions (three dimensional space, and time of arrival at specified points in space). The 4D-TBO model involves automated 4D Trajectory (4DT) Planning, Negotiation and Validation (4-PNV) supported by the Next Generation Flight Management Systems (NG-FMS) and by the ground-based ATM system (Ramasamy and Sabatini, 2015a). In order to support multiple conflicting constraints and operational/environmental/economic objectives, the planning and replanning of 4DT intents by these CNS+A systems will be based on Multi-Objective 4D Trajectory Optimisation (MOTO-4D) algorithms. These CNS/ATM systems are capable of generating optimized trajectories based on multiple operational/economic/environmental criteria whenever the necessity or opportunity arises (Gardi et al., 2015a). The 4-PNV validates 4DT intents through real-time negotiation, ensuring adequate separation for each aircraft resulting in a highly automated decision making environment (Gardi et al., 2015b). The vital communication link to support this function would be the Next Generation Aeronautical Data Link (NG-ADL). Initial 4-Dimensional (i4D) operations are being rolled out, which would work towards full 4D implementation estimated at 2028 (ICAO, 2013c).

# 3. Current regulatory framework for certification

ICAO is the foundation of aviation regulation, and currently comprises of 191 member States. There are 19 annexes published pursuant to the Chicago convention which provide Standards and Recommended Practices (SARPS) on international civil aviation. The annexes are recommendations, and the legally enforceable regulations are formulated through the rule making by the States. ICAO Documents (DOCs) provide supplementary guidance material.

Civil aviation regulations are mainly categorised into hard law and soft law, where the regulations and implementing rules comprise the hard law, and technical specifications, Acceptable Means of Compliance and Guidance Material (AMC & GM), operating standards, Advisory Circulars (AC), Civil Aviation Orders (CAO) etc. are soft law. Industry standards provide accepted methods to comply with regulatory requirements. Figure 4 describes the current regulatory framework for certification.

Figure 4: The regulatory framework for certification




The regulatory framework for airworthiness certification of aircraft and related products is governed by ICAO Annex 8 and Doc 9760. The framework outlines the requirements for initial airworthiness certification of aircraft and parts, and the requirements for continuing airworthiness. This includes the airworthiness certification basis together with organisational approval requirements for design, production, maintenance, operation and continuing airworthiness of aircraft.

The aviation authorities of the European Union, United States (US) and Australia are European Aviation Safety Agency (EASA), Federal Aviation Administration (FAA) and Civil Aviation Safety Authority (CASA) respectively. They are the concerned authorities of the main modernisation programs SESAR, NextGen and OneSky. The regulations pertaining to airworthiness certification of airborne systems prescribed by the said authorities are detailed in Table 1, together with the governing ICAO annexes (ICAO, 2001a, ICAO, 2006, ICAO, 2007a, ICAO, 2007b, ICAO, 2010b, ICAO, 2010a, ICAO, 2014).

Initial airworthiness certification of aircraft is established through the type certification and certificate of airworthiness processes which must comply with applicable certification specifications, airworthiness standards and national regulations. Certification of aircraft parts and appliances are in accordance with applicable Technical Standards Orders (TSO) (or ETSO in Europe and ATSO in Australia) or officially recognised standards.

Acceptable Means of Compliance (AMC), Certification Specifications (CS) and Advisory Circulars (AC) provide references to industry standards such as Radio Technical Commission for Aeronautics (RTCA), the European Organisation for Civil Aviation Equipment (EUROCAE) and the Society of Automotive Engineers (SAE) standards which provide industry best practices and accepted methods to comply with the regulatory requirements for certification. For example AC20-115C states that RTCA DO-178C is an acceptable means, but not the only means, for showing compliance with the applicable airworthiness regulations for the software aspects of airborne systems and equipment certification (Spitzer et al., 2014).

Table 1: Current regulatory framework for airworthiness certification (Transport category aircraft)

| | | European Union | United States | Australia |
|---|---|---|---|---|
| **Underlying Aviation Regulatory Body** | ICAO | European Commission | Federal Regulation Department of Transportation | Parliamentary Council |
| **National Civil Aviation Authority** | | EASA | FAA | CASA |
| **Aviation Legislation/ Standards** | ICAO Annexes (SARPS) and Docs | (EC) No 216/2008 Basic Regulation | Title 14 CFR: Aeronautics and space Subchapter C: Aircraft | Civil Aviation Act 1988, Civil Aviation Safety Regulations (CASR) 1998 |
| **Airworthiness Certification (including initial Certification)** | Annex 8 – Airworthiness of Aircraft, Annex 6 – Operation of Aircraft, Annex 17 – Aviation Security | (EU) No 748/2012 (Part 21), | Title 14 Part 21, Applicable TSO | CASR Part 21, Applicable ASTO |
| **Continuing Airworthiness** | | (EU) No 1321/2014 (Part M) | Title 14 Part 26, Part 43, Applicable Orders and AC | CASR Part 42 |
| **Certification Specifications/ Airworthiness Standards for Transport Category** | | CS -25, Applicable ETSO | Title 14 Part 25, Applicable Orders and AC, Applicable ETSO | CASR Part 25, Applicable CAO and AC, Applicable ATSO |
| **Certification Specifications/ Airworthiness Standards for Airborne CNS** | Annex 10 – Aeronautical Telecomm. | CS-ACNS dedicated to CNS, Applicable ETSO | Some regulations in Title 14 Part 91 and equipment certification under applicable TSO (No dedicated specification or standard for CNS) | CAO 20.91, CAO 20.18, Equipment certification under applicable ATSO, CASR Part 91, (No dedicated specification or standard for CNS) |

While Table 1 details the regulations for transport category aircraft, separate regulations are in place for normal, utility, acrobatic and commuter category aircraft, sailplanes, rotorcraft and balloons. Regulations are currently being developed for certification of civil unmanned aircraft.

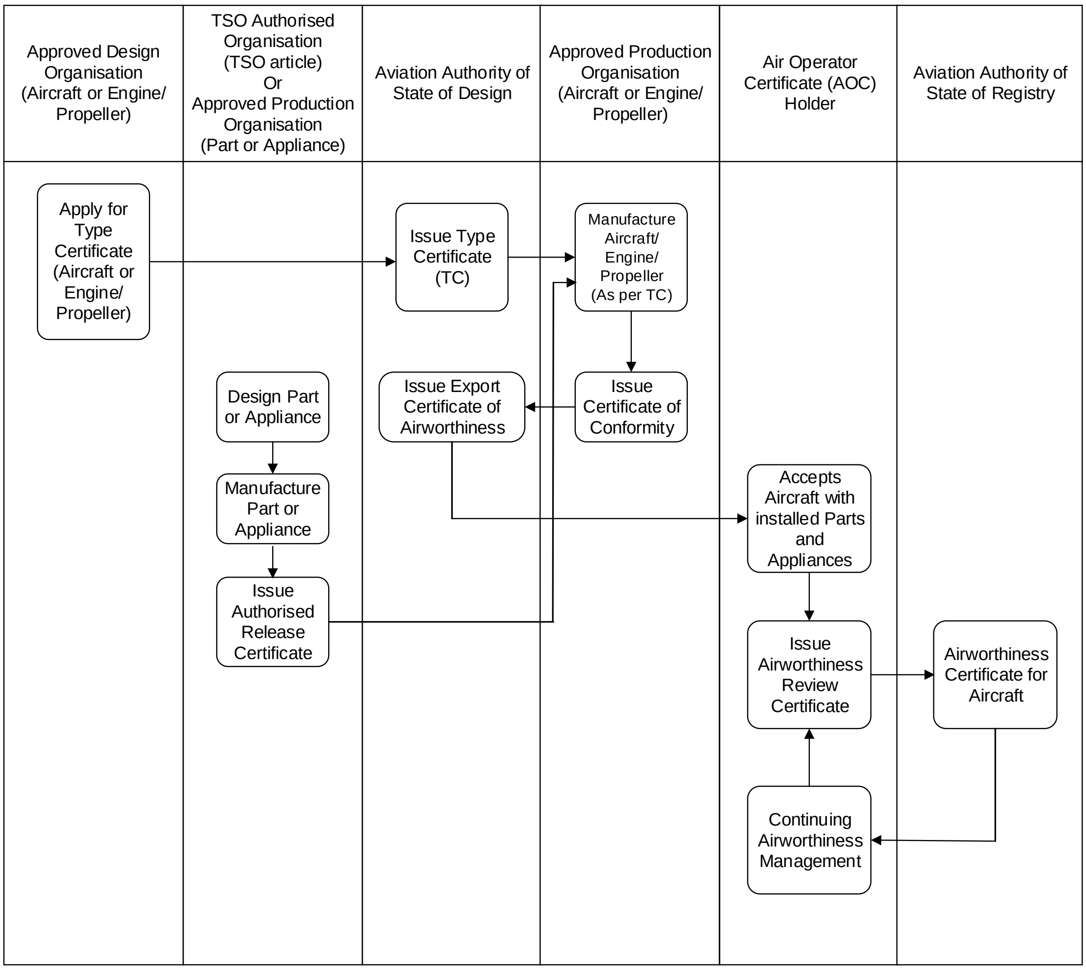
To discuss regulations on ATM which includes regulations for Air Navigation Service Providers (ANSP) and Air Traffic Service Providers (ATSP), Table 2 correlates the ICAO SARPS together with the regulatory framework of EASA, FAA and CASA.

Table 2: Current regulatory framework for air traffic management

| | | European Union | United States | Australia |
|---|---|---|---|---|
| **Underlying Aviation Regulatory Body** | ICAO | European Commission | Federal Regulation Department of Transportation | Parliamentary Council |
| **National Civil Aviation Authority** | | EASA | FAA | CASA |
| **Aviation Legislation/ Standards** | ICAO Annexes (SARPS) and Docs | (EC) No 216/2008 Basic Regulation | Title 14 CFR: Aeronautics and space Subchapter C: Aircraft | Civil Aviation Act 1988, Civil Aviation Safety Regulations (CASR) 1998 |
| **Air Traffic Management Systems** | Annex 14 – Aerodromes | (EU) No 139/2014 | Title 14 Part 139, | CASR Part 139 |
| | Annex 10 – Aeronautical Telecomm., Annex 11 – Air Traffic Services, Annex, Annex 15 – Aeronautical Information Services | (EU) No 1035/2011, (EU) No 1034/2011 | Title 14 Part 170, Title 14 Part 171 | CASR Part 171, CASR Part 172, CASR Part 173, CASR Part 174 |

A comparison of the certification of the airborne systems with the non-airborne systems of CNS/ATM reveals that only the airborne system certification is well established through the initial and continuing airworthiness processes (Part 21 and Part M/Part 42/Part 43 of the regulations). Figure 6 provides an overview of this intricate airworthiness certification process. Each aircraft, installed part, together with their design, production and maintenance organisations are individually certified or approved by the regulator for airborne systems. The non-airborne systems are not certified to a level of certification as that of airborne systems. Instead, aerodromes, ANSP and ATSP organisations are certified or approved by the regulators as per the regulations listed in Table 2 (ICAO, 2001a, ICAO, 2001b, ICAO, 2006, ICAO, 2007a, ICAO, 2007b, ICAO, 2013a, ICAO, 2013b). System certification is encompassed within the procedures of the approved ANSP/ATSP organisations, and not part of the direct regulatory approval/certification processes governed the regulator, hence not standardised. Safety assessment of non-airborne systems is mainly pursued through safety cases. Whilst this level of certification has been acceptable for traditional concepts of CNS/ATM, advanced technological concepts such as 4DT demands a higher level of safety, security, integrity and interoperability achieved through standardisation and the adequacy of the existing certification framework to fulfil these requirements is questionable.

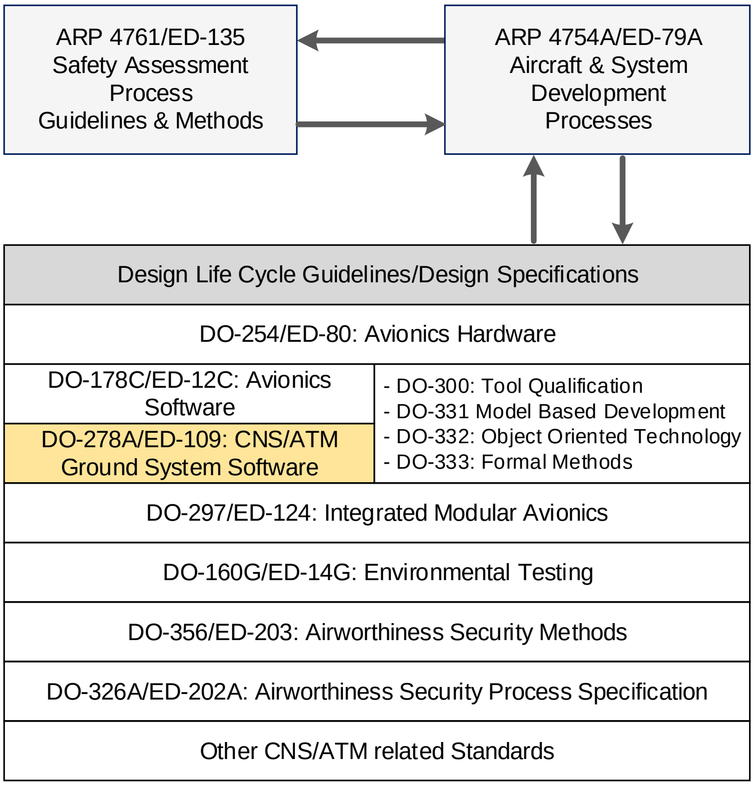
Figure 6: Current airworthiness certification process for airborne systems




The main industry standards used during the system development life cycle process are detailed in Figure 7 (RTCA Inc, 2005, RTCA Inc, 2011a, RTCA Inc, 2011b, RTCA Inc, 2014, SAE International, 1996, SAE International, 2010). Industry standards play a crucial role in certification through standards development by working groups consisting of industry experts. The standards provide a platform for certification by providing acceptable methods to comply with the regulatory requirements. They also enable standardisation of systems which is vital in an international industry such as aviation.

The main standard defining the aircraft and system development process is SAE ARP 4754A/ED-79A, which is to be used in conjunction with ARP 4761/ED-135 for safety assessment. This standard consists of safety assessment processes including Functional Hazard Assessment (FHA), Preliminary System Safety Assessment (PSSA) and System Safety Assessment (SSA). ARP-4761 and ARP-4754A have played an important role as traditional methods of safety assessment and system development of airborne systems. It is observed that there are no similar standards for the non-airborne systems. Furthermore, it is questioned whether traditional methods would be able to handle more complex systems being developed today (Leveson et al., 2015).

Figure 7: Current industry standards for certification




RTCA DO-254 for avionics hardware design assurance and DO-178C for avionics software certification are to be used in conjunction with ARP 4754A and 4761, together with DO-297 for integrated modular avionics and DO-160G for environmental testing. There are many other RTCA/EUROCAE standards published which provide performance standards for various CNS/ATM applications.

RTCA DO-278A providing Software Integrity Assurance Considerations for CNS/ATM systems is the parallel of DO-178C for non-airborne systems. While many other performance standards are being published in the rapidly evolving aviation industry in respect to system design assurance process, DO-278A is the only standard available for ground system design, and no similar standard to that of DO-254 is available for electronic hardware of ground systems. Furthermore, since the regulatory framework for non-airborne system certification has not being established, there is no standardisation of non-airborne ATM system hardware and software.

The current certification framework is a divided process for the airborne and the non-airborne systems of CNS/ATM. Although the airborne system airworthiness certification is well established, it is in isolation of the requirements of ground ATM systems.

Considering the integration and interconnectivity of the airborne and non-airborne systems of CNS/ATM, airworthiness of the aircraft is dependent on the service provided by the non-airborne systems.

Furthermore, next generation ATM systems involve highly complex electronic hardware and software. In this context, a unified approach should be considered for CNS/ATM system certification ensuring safety, security, integrity and interoperability of both the airborne and non-airborne systems.

# 4. Proposed new framework for integrated CNS/ATM system certification

The considered ontology for interoperability of airborne and non-airborne systems includes Signal in Space (SIS), System and Human Machine Interface (HMI). Currently available industry standards define the safety assessment process for airborne systems which should be extended to ground systems. Furthermore in addition to the current assessment of safety, reliability and resilience, new assessment processes should also account for system security integrity and interoperability. System integrity assessment should be captured as part of both safety and security assessment processes.

The proposed new framework for certification encapsulates the said assessment requirements which would then be included into the system development life cycle.

The tool for safety assessment already established under SAE ARP 4761 for civil airborne systems and equipment is extended into the CNS/ATM system safety assessment by taking into consideration some assessment criteria such as FHA, PSSA and SSA. Considering the complexity of the systems, more attention should be given to systemic failures in addition to random failures. Verification means would have to be re-defined taking into consideration the specific feature and functionalities of CNS/ATM systems, and the subsystems of SIS, System and the HMI.

Security assessment is a growing concept in aviation, and RTCA standards recently published as DO-326A for airworthiness security process certification and DO-356 for airworthiness security methods and considerations, which cover the airworthiness side, should be extended to encompass the security assurance of ground systems. While historically aviation industry did not require certification of regulatory compliance to interface with the aircraft, “Groundworthiness”, a new term in civil aviation is one which would be more prevalent in the industry and would require much more work in this context (Kölle et al., 2011).

Integrity is essential for the safe and secure operation of CNS/ATM systems, mainly in the context of systems software, and in various concepts such as Global Navigation Satellite System (GNSS) applications, satellite communication systems, terrain and warning systems, ADS-B systems, TCAS systems and Aeronautical Information Systems. Concerning software integrity, RTCA DO-178C and DO-278A recommend COTS software integrity assurance case be developed by providing a rationale for demonstrating that the software meets its requirements through a rigorous presentation of claims, arguments, evidence, assumptions, justifications, and strategies. A more robust integrity assurance may be required for complex systems of CNS/ATM.

Sabatini et al have presented an Avionics-Based Integrity Augmentation (ABIA) for mission- and safety-critical GNSS applications (2013a), which considers both the predictive and reactive nature of GNSS integrity augmentation with built in integrity alerts, namely Caution Integrity Flag (CIF) and Warning Integrity Flag (WIF). These facilitate the Prediction-Avoidance (PA) and Reaction-Correction (RC) functions of the ABIA system. An integrity assessment model will typically verify system’s capability to maintain its integrity in performing its intended functions as exemplified in the case of GNSS integrity augmentation systems.

Figure 9 depicts the proposed evolution of the ARP 4754 standard (Aircraft and System Development Process) and ARP 4761 standard (Safety Assessment Process) for the CNS/ATM context. These standards currently focus only on aircraft systems. The new framework as shown in this figure encompasses the integrated airborne *and* non-airborne CNS/ATM systems, for the purpose of certification. The primary process of this framework is the CNS/ATM System Development, which consists of design, development, verification and validaton of the system, taking into consideration the system operational and functional requirements and the operating environment. The development process includes the system hardware development life cycle and the software development life cycle. The following processes contribute to the CNS/ATM System Development Process and are intended to be a vital part of the overall certification process.

- System Safety Assessment Process,
- System Security Assessment Process,
- System Integrity Assessment Process, and
- System Interoperability Assessment Process.

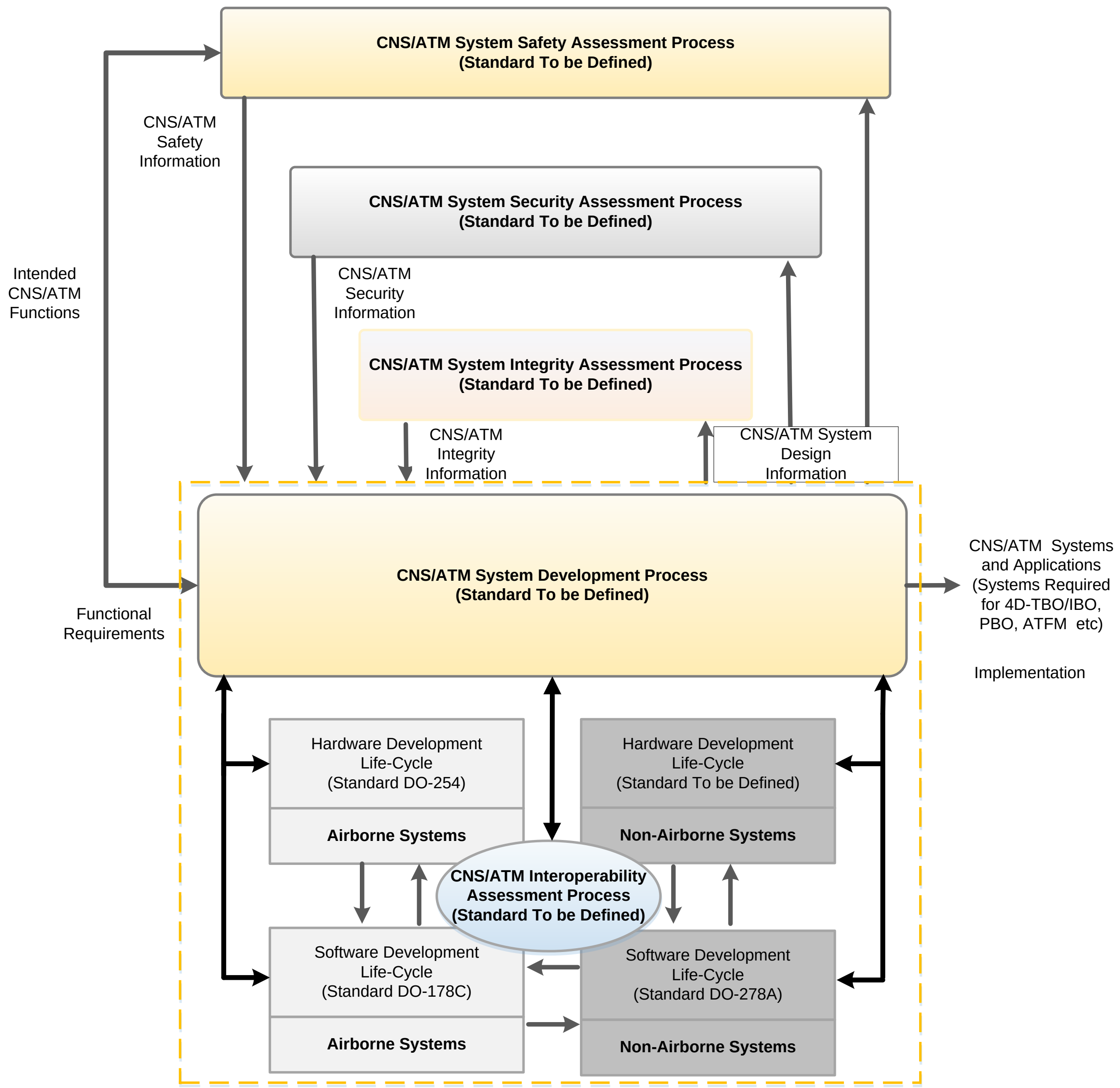
System safety assessment currently available for airborne systems is to be extended to non-airborne ATM systems. The safety requirements defined through the assessment process are to be assured during the system development. In addition to safety assessment, security assessment is also considered in the proposed model, which is as crucial as safety assessment, considering the extensive involvement of Information and Communication Technology (ICT) in the new applications being developed for CNS/ATM. A growing concern which affects all information technology systems and networks is cyber security, which is not unique to ATM. New systems used by SESAR and NextGen would be vulnerable to this threat which must be mitigated through global cooperation, with a fundamental role played by ANSP (CANSO, 2014). System security assessment at the design and development stage is vital in this regard

While software integrity is taken into consideration in DO-178C and DO-278A, and in performance standards defined for GNSS and Automatic Dependent Systems (ADS), the proposed model aims to define integrity assessment tools which can be used for all CNS/ATM systems.

Interoperability is essential in the context of seamless operation of CNS/ATM taking into consideration the three essential components of the system namely, the signal in space, the system (hardware and software) and the human machine interface. The airborne systems should be interoperable with the non-airborne systems. The systems used by various ANSP/ATSP should also be interoperable with each other for the continuous application of CNS/ATM functions throughout all phases of flight of the aircraft across airspace boundaries geographic regions. Furthermore, aircraft avionics should be interoperable with each other for information sharing and surveillance functions.

Considering the example of 4DT operations concept, the algorithms of the airborne NG-FMS avionics systems must be interoperable with that of NG-ATM ground system. The required level of interoperability should be maintained during technological changes, system upgrades and even system degradation for continuous 4DT operation. The capability of the system to ensure this interoperability is to be assured through the assessment processes during system design, development test and evaluation. Required levels of interoperability should be elicited by apposite standards and regulations.

Figure 9: Proposed new unified certification framework for integrated CNS/ATM




Means of Compliance provides methodologies and descriptions as to how compliance may be demonstrated for certification requirements. Acceptable Means of Compliance (AMC) and Guidance Material (GM) provide guidelines for each compliance requirement. Following matrix given in Table 3 has been compiled, based on AMC/GM of airworthiness certification and has been extended to capture the identified additional assessment requirements of security and interoperability in addition to the already established assessment requirement of safety in the CNS/ATM environment. This provides documentation and testing methods that can be used to demonstrate compliance of design evaluation, test, inspection and equipment qualification of the system concerned.

Table 3: Means of compliance matrix

| Type of Compliance | Means of Compliance | Associated Compliance Documents |
|---|---|---|
| Design evaluation (for CNS+A System) | Compliance statement<br>Reference to type design documents<br>Election methods, factors etc.<br>Definitions | Type Design documents<br>Recorded statements |
| | Design review | Descriptions, drawings |
| | Calculation/Analysis | Substantiation reports |
| | Safety assessment | Safety analysis |
| | Security assessment | Security analysis |
| | Integrity assessment | Integrity analysis |
| | Interoperability assessment | Interoperability analysis |
| Tests | Laboratory tests | Test programs<br>Test reports<br>Test interpretations |
| | Ground tests on related product and function | |
| | Flight tests | |
| | Simulation | |
| Inspection | Design inspection/audit | Inspection or audit reports |
| CNS Equipment qualification | Equipment qualification | Note: Equipment qualification is a process which may include all previous means of compliance |

# 5. Conclusions and future research

Research and development programs including SESAR, NextGen and other regional and global projects such as ASBU are currently underway with the aim of designing tomorrow's air transportation systems The evolutionary systems are expected to overcome the challenges currently faced by the industry for increased air capacity, efficiency and environmental sustainability. The technological developments, increased automation, connectivity and information sharing are foreseen to overcome the said challenges of the industry, which however bring forth its own concerns in terms of safety, security and related certification. Novel technological developments including 4D trajectory based operations require greater integration between airborne FMS and ground ATM systems for real time planning, negotiation and validation. While initial 4D trajectory based operations are currently being rolled out, full 4D operations are planned for the the next decade. Data link communication will be the backbone of future CNS/ATM systems, with data communication replacing voice communication to minimal usage and emergency situations. Information sharing between airborne systems and various stakeholders on ground including will be enabled through SWIM. In this context, this paper reviews the current regulatory framework considering the published ICAO SARPS and other documents, and the implementing regulations of the national aviation authorities with a focus on EASA, FAA and CASA, together with industry standards for the certification of aviation systems. Most regulations and industry standards currently in place are only for airborne system certification. With regards to the non-airborne systems, a gap of increasing relevance is observed in the certification of Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) systems. A new unified certification framework is therefore proposed, taking into consideration the integrated nature of airborne and non-airborne systems of CNS/ATM, requiring a total system approach for the assessment of safety, security, integrity and interoperability aspects in the design, build and test phases of the system development life cycle. Future research will entail development of the assessment methodologies and tools required to implement the newly introduced framework for integrated CNS+A certification.

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